NeWater

D 1.1.5

INTEGRATING KNOWLEDGE ACROSS DISCIPLINES

Experiences from the NeWater project

Report of the NeWater project -
New Approaches to Adaptive Water Management under Uncertainty

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1 POLICY SUMMARY

The starting question for this deliverable was how to create a new adaptive management concept that can integrate insights from various disciplines and connect people from different institutional backgrounds. From literature research and empirical research on the NeWater project we identified challenges for cross-disciplinary knowledge integration, we evaluated interventions for connecting multiple knowledge frames, we analyzed the process of group model building with UML and formulated recommendations.

Cross-disciplinary research has arisen from a growing number of complex problems for which knowledge of a single scientific discipline or societal field is insufficient, but presents important challenges: (1) collaboration and integration of knowledge requires in depth discussions that are time-consuming; (2) the recursive process of problem structuring and restructuring is often at odds with the sequential planning of project activities; (3) participation and mutual learning are crucial but need to be carefully structured and sequenced; and (4) management and leadership faces the difficult challenge of balancing in depth exploration with timely delivery of tangible results.

In Chapter 4 we present an article that analyzes the cross-disciplinary collaboration from a framing approach, focusing on the intensive process of knowledge integration over the first 18 months of the project. A number of interventions can enhance the connection of varied disciplinary frames in research collaboration: (1) highly interactive work forms allow for open and mutual questioning and connect both people and concepts; (2) separating the complementary roles of presenting versus chairing or facilitating the meeting allows for more opportunities for open discussion across different frames; (3) group model building and translating disciplinary and cross-disciplinary insights into a common formal language helps to make mutual assumptions explicit; (4) using concrete or stylized case situations as common ground allows participants to illustrate and find connections between varied disciplinary frames.

In Chapter 5 we focus on the process dynamics associated with exploring and developing theoretical concepts across disciplines through group model building with UML, with the explicit aim of reaching an integrated conceptual framework. Through a close analysis of group model building sessions using UML, three core dilemma's for knowledge integration were identified: (1) the dilemma of simplicity versus complexity refers to the tension between the search for a general and abstract overview, on the one hand, and the attempt to acknowledge and capture the rich, local, detailed and specific knowledge in a model, on the other hand; (2) the dilemma of constraining versus containing refers to the tension between the delimiting the scope of a model and specifying a starting point, on the one hand, and keeping both form and content as open as possible to integrate diverse forms of knowledge; and (3) the dilemma of defining versus refining involves tensions between perfect representation on the one hand, and pragmatic learning on the other hand.

We conclude with the following general recommendations for large cross-disciplinary projects: (1) including a preparatory proposal phase for thorough exploration of opportunities of between researchers and stakeholders (2) flexible funding, planning and operational arrangements to allow for a recursive research process; (3) a project size that allows frequent interaction opportunities between researchers and between researchers and stakeholders to allow for mutual learning and in depth exploration; and (4) enhancing learning opportunities from one project to the next.

2 OVERVIEW

This deliverable was produced as part of Task 1.1.5 ("Promote processes of social learning and knowledge synthesis within the project"). The background for this task is a concern for how a new adaptive management concept can be created that can connect various disciplines and people from different institutional backgrounds. Making the connection between often very different perspectives or frames is necessary between the different disciplines, but also between scientists, governmental institutions and interest groups in the case studies. Throughout the project we have contributed ideas for stimulating social learning on the basis of past experiences and research, by way of observations, feedback and joint reflection. At the same time new research was carried out in NeWater in order to improve our knowledge of such processes, on the basis of a more detailed analysis of discussions project meetings.

In Chapter 3 we present three meeting reports, which were prepared as part of our ongoing task of observing project meetings, inquiring into the experiences of participants, and providing reflections and feedback.

In Chapter 4 we present an article that analyzes the cross-disciplinary collaboration from a framing approach, focusing on the intensive process of knowledge integration over the first 18 months of the project. We assess a number of interventions undertaken from a social learning perspective that aimed at integrating and connecting multiple frames.

In Chapter 5 we focus on the process dynamics associated with exploring and developing theoretical concepts across disciplines through group model building with UML, with the explicit aim of reaching an integrated conceptual framework. We selected a representative group model building episode and analyzed the tensions or dilemma's that appear in such a process.

In Chapter 6 we bring together the practically relevant results discussed in the previous chapters, in the form of recommendations for fostering knowledge integration in cross-disciplinary research collaboration.

Although the challenges and interventions for dealing with multiple frames were relevant beyond the first 18 months of the project, and although tensions and dilemma's similar to the ones observed in the analyzed group model building episode could be observed at a range of other project meetings, it's important to note that this deliverable is not to be considered as a *complete* study of the *whole* NeWater project. The focus is necessarily selective, with knowledge integration, framing, social learning and group model building as core concepts. Furthermore studying the entire NeWater project in all its complexity would have required a much greater investment of time and resources than were foreseen for this task and deliverable. Our report is therefore a form of bracketing particular episodes or issues, in order to focus on some aspects, recognisable to the participants, and related to knowledge integration in the Newater project, and likely of more general importance for cross-disciplinary research collaboration.

3 NEWATER MEETINGS: OBSERVATIONS AND REFLECTIONS

3.1 Reflections about the design and process of the NeWater kick-off meeting

The challenges for the kick-off meeting were considerable. The proportions of the NeWater project resulted in a great number of participants from 35 institutions, and in a wide range of issues to be covered. Furthermore the project aims at connecting knowledge from a variety of disciplinary fields, which is reflected in strong interdependencies within and between work packages and work blocks. Dealing with this complexity was the challenge for the kick-off meeting.

Short evaluation by WB coordinators

In a short evaluation session with project and work block coordinators after the kick-off meeting, we gathered the following reactions with respect to the meeting. Each work block coordinator was asked to mention one positive and one negative point about what the meeting reached or did not reach.

WB1: People recognized where they fit in, they became aware of linkages. We did not yet solve all linkages between WP and cases, but between WB we are more clear than at the start. In general I found it positive, we could join.

WB2: People could see each other face to face. We got a feel of the high complexity of the project, which is both good and bad. People got to know what they can expect from each other.

WB3: There's a high degree of complexity of coordination: we are really just starting now and we made some good progress, but the task is far beyond scope of this meeting. It is not possible in one meeting.

WB4: We have a better overview of all products, about interactions between WB and interdependencies: this is positive. Negative: there was not so much time as I expected, so we did not get that far.

Observations and suggestions

- This meeting faced the double task of, on the one hand, getting informed about the work to be done, and on the other hand, getting acquainted with each other and finding your place in the project. We think the meeting was more successful in getting through the information than to get to know each other. A lot of people still remained unknown to each other.
- The basic design of alternating work sessions between different levels (project/WB/WP) was useful. Mixing up the groups the first afternoon was interesting as dynamic, but you need a common theme; e.g. adaptive management was common and the discussions turned out well, but tools was not enough of a common theme enough for all participants to connect to.
- Timing was good and the schedule was adapted where necessary
- In the various meetings presenters faced often the double role of presenting a lot of content and chairing the meeting. Presenting calls for clear explanation and information flow from presenter to public. Chairing the meeting calls for stimulating participation, checking comprehension, following up on comments and explicating (and checking) the goal of the meeting and what we expect as outputs. It's not an easy job to combine both these roles in one person, and presenters seemed to have difficulties with it.
    - Suggestions: specify more clearly goal and expected output of a meeting, if applicable clarify methodology and appoint a chair for the meeting apart from the presenter
    - The chair can summarize agreements/disagreements, emphasize certain points, facilitate the discussion and provide background from where we start and where we will feed into
- Meeting format was mostly presentation following by a question and answer session. This generally does not stimulate much discussion. The general "questions?" doesn't make it easy for participants to contribute since it is not clear what contribution they are expected to make. Asking specific questions on specific issues can be a way to stimulate discussion.

- What to do with reporting in plenaries? Some reports only touched upon general conclusions without giving an idea of the arguments for them or points of discussion. Sometimes these conclusions become too general to be meaningful. The challenge is to give a differentiated picture in a concise manner so the public gets sufficient insight in how the meeting went, what was discussed, what can be concluded and what issues remain to be dealt with. Giving an overview on the basis of an initial well known scheme or overview slide can
- There wasn't very much opportunity to get acquainted with persons and institutes. Introducing the participants by presenting yourself and what you are usually doing in the smaller meetings is important to stimulate participation and also informal discussions afterwards. In this way groups can start to develop.
- A lot of information had to be given very fast. Inevitably, a lot of confusion arises. Participants come from very different backgrounds and a lot of talk has no meaning to a part of the participants. It was important that these differences in approach and frameworks were acknowledged and valued in the opening presentation. The meeting format didn't provide many opportunities to deal with the confusion, since this requires mutual questioning until a sufficient level of mutual understanding is reached.
- This said, group size is major limiting factor for the possibilities of getting acquainted, getting a good discussion and dealing with confusion. Groups at WB or WP level were mostly still too big to allow for fluent small group interaction.

Ideas for follow-up and e-communication

- From the point of view of a project participant a combination of information delivery and information retrieval seems adequate.
    - The existing mailing lists for work blocks are a form for information delivery. A website for sharing files is a form of information retrieval.
    - We think mailing lists on the level of work blocks need to be complemented by mailing list for work packages, or even tasks in some cases.
    - As a supplementary form of information retrieval, a search function through all mailing lists would create the possibility for accessing information about related activities, and make possible the establishment of direct links between work packages/tasks.
    - Another possibility for establishing cross-links is to make possible subscriptions on issue-based lists that cross-cut the WB/WP hierarchy.
- There seem to be a need for evolving working document with updated work descriptions and connections between tasks (hyperlink way, or UML, …).
- Also, available information should include links to details about participants and institutions (preferably with photographs).

While Cundill, Fabricius and Marti (2005, p.8) label the "trade-offs" which they identified in approaches to cross-disciplinary knowledge integration differently, the quote below indicates that these dilemma's are recognizable beyond the Framework Development Workshop in Steinfurt and beyond the NeWater project:

> In terms of research approaches, the three most important trade-offs were related to the following issues: (1) predesigned frameworks are convenient, but they eliminate alternative perspectives; (2) transdisciplinary assessments are inclusive and comprehensive, but their research outcomes are often superficial; and (3) predesigned questions make for more rigorous and comparable assessments, but they place constraints on reflexive learning processes" (Cundill, Fabricius & Marti, 2005, p.8).

As suggested earlier, the dilemma's identified in our analysis can be coupled to Wenger's notions of 'reification' and 'participation' (1998). These were explained earlier in this report, and presented as two interdependent activities in the learning process. In our data, reification puts the emphasis on the framework as a "specific notation", "a structure" or a "representation"; participation emphasizes the framework's potential in terms of "linking all those (project) activities" and "jumping in the water together, … getting into difficult questions together." In those terms, our data suggest that a significant part of the meeting was spent negotiating an acceptable balance between participation and reification.

Working towards guidelines for cross-disciplinary research, we refer to Pennington (2008, p4) as a starting point: "Differences in fundamental assumptions must surface. This is not accomplished through set agendas, and assigned tasks. It primarily requires a facilitator to set up and maintain the field of inquiry." It can be said that the Framework Development Workshop did bring a number of fundamental assumptions to the foreground and that the WP17 group dealt with this constructively. One of the contributing factors appears to be the relative flexibility of the workshop leaders. Reading Pennington's "maintain a field of inquiry" as a reference to containment, our study of cross-disciplinary collaboration suggests that a facilitator has several options in this regard. The main option pointed out by this analysis involves awareness of the dilemmas identified – and possibly others – in the evolving collaboration. As group members take different positions with regard to these dilemma's, these represent sources of tension and potential 'stuckness' of the GMB. We propose that early recognition of the dilemma's related to knowledge integration makes them more manageable.

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3.2 Process reflections on the NeWater WB1 April 2005 meeting

3.2.1 Reflections of the participants

3.2.1.1 Process reflections DAY 1

What were helping moments for coming to a more qualified understanding of adaptive management?

- we discovered that there were are a number of things still unclear (concepts, models, assumptions) but we realized that it is probably for everybody still unclear, that was quite a relief
- work in the different groups, trying to understand the basic questions
- discussion on e.g. where does an adaptive regime stop, because there is still no agreement on working definitions for basic concepts (adaptivity, regimes, …)
- we need examples for mutually understanding what we mean, we may not have enough case studies in the project the idea that system should be precautionary was new and interesting to me, my mental model about adaptive systems evolved
- we should keep on going beyond limits, using examples from other domains (Catholicism, slavery, …)
- we defined and distinguished some key concepts more clearly, e.g. adaptivity and vulnerability
- break-out groups, the most interactive work form, were the most interesting and useful discussions
- opening session presenting the different views of everybody were very helpful
- smaller groups were really positive, working on a clear product keeps you focused

3.2.1.2 Process reflections DAY 2

What learning conclusion from the way we have been working together today, which are useful for the future work in this project?

- I experienced as positive that everybody is very willing to listen to each others views and opinions. A lot of openness.
- Very good atmosphere, trial and error approach without feeling bad about it is very constructive. At the same time a bit uncomfortable about randomness: the composition of the group does matter in what we have as result, we should be very conscious about it. I felt dominance of the stakeholder paradigm and some other things were lacking. Too open, too progressive as a way of working when you work with (ministry) stakeholders.
- Atmosphere is different than in a stakeholder meeting. There is a lot of prejudice about how stakeholders behave, in reality some are really willing to engage in it.
- What helped me was talking about our assumptions about change and that helps me to understand the differences in the room.
- I had a low moment this afternoon, because it seems like every meeting is starting anew, that seems to be common, this project allows for building it up, I'm tired but happy
- We have to think about what we can expect and reach in these workshops, and we need to take care not to stereotype stakeholders.
- We were discussing a lot about IWRM, but we need to focus on the specificity of adaptive management. We were not separating the new from the old. We do not have to invent IWRM again.
- There is a tension with complexity of topic and need to have examples, these terms should be clear to everybody so a common understanding must be developed, you need a more conceptual framework, we are still far from it.
- Thinking about how we can connect to other projects and make use of already existing knowledge

- I needed these days to get accustomed to the different languages of the participants and their backgrounds
- Discussions in smaller groups
- We have both tangible and intangible outcomes, like working with the group, which we will realize later
- Early exemplary case approach was very helpful, and to have case study resource people around

3.2.1.3 Process reflections DAY 3

What were moments of discovery about your own and other's understandings?

- Whole variety of research from different perspectives, good background but a lack of understanding
- Break-out groups on the same questions: in each group the same question came to different answers, in the discussion we were questioning a lot of things, including regime, we were questioning each point we elaborated before, generating new ideas
- Everyone should explain AM as he/she understands it in the case studies
- Moderation very good, everyone able to look beyond one's own perspective in the open break-out groups, we can now position ourselves better
- Good questions and structures
- Aha moment when I saw Claudia's presentation on the levels, really helpful
- At the end of the market, I felt that something started to happen, I didn't want to get back to the plenary
- Everyone became aware of the different perspectives available as a start to change
- Jan presenting Tisza, and explicitizing theories of change and applying them
- Participatory approaches have dominated the discussion, lack of integration between social and natural components
- Something is puzzling me, all these models that calculate things, how are they adaptive?
- Frustration on having to start from zero for the understanding of adaptive management
- I experienced a sequence of events:
    - Expectation: building a house in a classical way, with a clear plan, laying the fundaments and get to the more specific
    - Frustration: end of break-out groups, damn we cannot do this
    - Relaxation: that's fine, we have a lot of material and workers and some start building here and there, we don't have the exact picture but we are there and we have the things we need
    - Illustration: even policy makers are going into that direction
- I've explained so often what AM is, so that's frustrating, but there's not a given framework ready, we are developing it, heard a lot of good ideas, I found that very positive
- Break-out groups yesterday afternoon on a very concrete case, a lot of attention and energy, focusing on a concrete reality was enough to keep on contributing
- I came to realize what a short time frame we have in the social sciences, a couple of years only, and we attribute change often to top management or a couple of people, but other drivers of change are more given by the context: riding the waves of economic booms for example,
- If we want to work with the diversity of the group, the card method (aggregation and prioritizing of responses) has to be used very carefully
- We had a group in which no one imposed something on others, this is not always the case, I would like to thank Claudia for the preparation, for finding the balance between flexibility and structure for leading the meeting

- In meetings like this it's important to have as many moments of discovery as possible. We were working on the content level, and we do our best to structure the process, nevertheless it's still in the process that the discoveries are made. It's Important to have moments of discovery, but they are often unexpected.

3.2.2 Reflection on meeting design and process (COPP)

- The different meanings attached to the concept of regime illustrate well the impact of the variety of backgrounds involved in the project. Different disciplines use different criteria for defining the boundaries of the concept. Also, projecting an ideal state is different from identifying minimal necessary and sufficient conditions for a system to be adaptive. In the definition of levels, different ways of defining emerged:
    - geographical: local, catchment, basin, global
    - institutional: local, regional, national, international, continental, global
    - time scale: changing in cycles of years, decades or centuries
    - …
- Case studies as background were useful, but could have been used even more. Ideally good preparation material should be available and studies, so that dependency on the case initiator is minimal, and real debate can develop. The case presenter can still keep the important role of explaining and linking the case with concepts.
- Complementary roles of presenting versus facilitating worked well. The presenter – especially when responding with ad hoc contributions on concepts or summaries or presentations can concentrate on the subject. The facilitator is in touch with the audience and prepares the coming interactions. It proves very comforting for the presenter.
- There was some procedural conflict because some people have ideas themselves about how to proceed or which methods to use. This is a normal process in developing groups and indicates that the group is no longer entirely dependent on the chair/facilitator. Two options can be distinguished in achieving structure, namely (1) to define structure beforehand or (2) to introduce it when needed and to acknowledge the potential procedural conflict on working methods to alleviate the tension.
- How did the working methods affect the process of connecting disciplinary frames? At certain occasions the cards methodology and other round robin methods (each give a couple of statements, contributing elements, priorities etc.) led to 'piling up' or concatenating rather than connecting. Connecting asks for deepening, for focusing on a limited number of aspects – rather than making (long) lists.
- There's a difference between analyzing interdependencies in a descriptive way, providing an overview (interaction matrix or graphical loop model) and dealing with interdependencies (negotiating work agreements, commitments and work forms). The open market session for dealing with interdependencies among WP's generated a lot of energy in the participants, and they were able to structure the interaction themselves at that point. Issues of personal concern could be discussed directly and direct face-to-face commitment and planning was started up.
- Two days may be limit for concentration for such a meeting. It relates also to what kind of psychological contract we had for the meeting: informative session, who is responsible for what, kind of personal contributions, … . We realized the importance of being actively involved in the process of developing together a conceptual framework in order to understand the how and why of certain elements. Arriving too late or leaving too early the workshop disturbed this shared process and produced a feeling of having to start again explaining and building up the framework with the late-comers.

3.2.3 Challenges for the future

- One major issue needs continuous reflection for each meeting/session: what do we do with the groups? planning, work together, improve communication, generate ideas, …

- How much connecting do we need for working together? Where do we need to develop a new trans-disciplinary field? Where can we apply a disciplinary division of tasks and connect only at the border? How can we identify these grey zones or overlaps or cross-border connections?
- How to manage the interdependencies in the project in a way that is consistent with the conceptual interdependencies in the water management regime?
- The conceptual frameworks are not meant to be used only by WP1.1 and 1.7 but by all institutes and WP's involved in Newater. We need to transmit the newly generated insights of WP 1.1 and 1.7. to the rest of the project.
- Later meetings will need the presence of the water management stakeholders as well, creating a new challenge in addition to the conceptual one, namely their espoused theories about adaptive management, and their theories-in-use

3.3 Observations about representing knowledge with UML – the Steinfurt and Sevilla meetings

- Using UML in group discussions helps to make mutual assumptions explicit, because everybody attempts to translate his or her concepts into a common language. In selecting aspects, labelling them, drawing the relations and labelling the relations, differences between participants emerge and can be discussed. It also helps to keep the attention focussed on the developing diagram and it results in a tangible output of the discussion (one or more diagrams).
    - "making these diagrams is useful to access knowledge that's in someone else's head"
    - "with the diagrams you have to become more precise"
    - "very useful for the discussion because it focuses the discussion on a visual image"
    - "we were talking and talking until now but now we have a clear result"
    - "it is positive that each of the groups made good products"
- Making the diagrams helps to identify where knowledge of a system or process is incomplete. Information about some elements or links may be missing.
    - "I thinks it helps to identify knowledge gaps, to see where our description is incomplete"
    - "It was interesting to see the bits of information that were lacking"
- It's important to embed the making of diagrams in a larger process and clarify the goals of making them (knowledge representation, integration, facilitating discussions, …). Otherwise, people may not see the point of making the diagrams, or at the other extreme, people may start using UML indiscriminately.
    - "The first big discussion was: how we can use these diagrams or why do we need them in the process, and if we now start with this are they really used later"
    - "we should be clear about what we want to get out of it from the beginning so that we don't make a diagram for the sake of the diagram"
- Keeping track of the developed UML diagrams and limiting their number by prioritizing will not be an easy task.
    - "we should be very critical about which ones we make"
- In terms of finding a mutually workable representation, the top level (matrix) itself may be the biggest challenge, since this captures world views on a high level of abstraction. In some cases, starting from representations of concrete subsystems may be easier (e.g. starting from the most important issues in a specific case).
    - "We spent much time on the matrix and which cell was the most relevant for us. We ranked all the cells independently, and there were very different perceptions"
- A workable equilibrium between technically correct UML and easily understandable UML should be found. The best diagrams may be those where "UML-experts" watch the formal correctness, while "UML-laypersons" assure it is easily understandable for non-experts as well.
    - "formally correct UML diagrams are not necessarily the most easily understandable ones"
    - "we need set quality standards, if not we are prone to ambiguities in interpretation, we need quality check"
- A characteristic of UML as a formal language is that the visual lay-out of elements and relations in a specific view is technically meaningless: as long as the entities, attributes and

relationships remain the same, you can rearrange the visual representation as you like without affecting what it means in UML. People are used however to derive meaning from the visual aspects of a diagram (above-below, left-right, close-distant, …). The advantage is that UML does not rely of these often implicit and possibly diverging meanings of the visual aspects of the diagram. The disadvantage is that people may still read those meanings into the visual aspects of the diagram and make the wrong conclusions.

- It's important to keep track of the uncertainties, assumptions and choices involved in making the diagrams. They imply a lot of choices in selecting aspects, formulating them and relating them to each other. Documenting the choices that were made and the reasons for them can help others understand the diagrams better.
- Working with UML as a tool for documenting and exchanging knowledge can be interpreted with Wenger's participation-reification concepts. Participation, meaning here involvement in the development of knowledge, needs reification, for example diagrams (as different from papers or reports), to store and 'transport' this knowledge. But reifications always needs participation: people need to be willing to learn to talk the new language and to work with it, otherwise the diagrams remain meaningless. This learning process will have to be partially redone every time a broader group is expected to work with the new language. In this sense it may be important to keep track of the people who participated in making the diagram.
    - "I don't think we should expect miracles about communicating this to external people, they will have a limited understanding of it"
- A general concern with respect to the integration of different theories into a conceptual model, is the difficult distinction between (1) connecting concepts that represent different parts of reality, and (2) connecting concepts that categorize differently the same part of reality. The problem is that our concepts to some extent define what we take to be the reality. I think the more cautious approach is to allow for parallel representations of parts of reality where or when necessary (different ways of framing the issue), and try to identify overlapping parts and look for complementarities where possible.

4 A FRAMING APPROACH TO CROSS-DISCIPLINARY RESEARCH COLLABORATION

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Research, part of a Special Feature on New Methods for Adaptive Water Management

A Framing Approach to Cross-disciplinary Research Collaboration: Experiences from a Large-scale Research Project on Adaptive Water Management

Art Dewulf [1], *Greet François* [1], *Claudia Pahl-Wostl* [2], and *Tharsi Taillieu* [1]

ABSTRACT. Although cross-disciplinary research collaboration is necessary to achieve a better understanding of how human and natural systems are dynamically linked, it often turns out to be very difficult in practice. We outline a framing approach to cross-disciplinary research that focuses on the different perspectives that researchers from different backgrounds use to make sense of the issues they want to research jointly. Based on interviews, participants' evaluations, and our own observations during meetings, we analyze three aspects of frame diversity in a large-scale research project. First, we identify dimensions of difference in the way project members frame the central concept of adaptive water management. Second, we analyze the challenges provoked by the multiple framings of concepts. Third, we analyze how a number of interventions (interactive workshops, facilitation, group model building, and concrete case contexts) contribute to the connection and integration of different frames through a process of joint learning and knowledge construction.

Key Words: *adaptive management; cross-disciplinary research; framing*

INTRODUCTION

When researchers from different institutes and disciplines join up to study a common issue, they face a number of challenges. Communication and coordination problems, misunderstandings, and mismatched expectations easily arise. We contend that an important challenge in these cross-disciplinary endeavors is dealing with the diversity of frames or perspectives that people use to make sense of the issues of importance in a specific research context. In this paper, we outline a framing approach to cross-disciplinary research and use it to study a large-scale cross-disciplinary research project on adaptive water management.

The large-scale research project we studied is an EU-funded project, which brings together people from various nationalities, cultures, institutes, and scientific disciplines. The aim is to develop the scientific base and practical methods to implement an adaptive approach to water management, drawing on a wide range of fields such as hydrology, management, ecology, geography, systems sciences, economics, psychology, and political science. People from these different backgrounds are interdependent in performing their tasks and achieving the goal of developing a workable approach to adaptive water management. At the same time, they pursue their individual interests and want to achieve insights related to their own fields of specialization. This turns the project effectively into a multi-actor collaborative effort (Gray 1989).

Although much has been written on the necessity and benefits of cross-disciplinary research, relatively little is known about how it actually works. In this sense, cross-disciplinary research itself becomes a crucial research topic if we want to achieve a better understanding of how human and natural systems are dynamically linked. Therefore, much effort is devoted within this project to investigating and monitoring experiences within a cross-disciplinary and integrated research approach. The current paper analyzes this process over the first 18 months of a 4-year project.

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In developing a framing approach to cross-disciplinary collaboration, this paper focuses on three related issues or research questions, which each have a theoretical and an empirical aspect.

1. How can one understand frame differences theoretically in the context of cross-disciplinary collaboration, and how do frame differences manifest themselves in the studied project?

2. What challenges do these frame differences pose for research collaboration and how do they manifest themselves in the studied project?

3. How can these frame differences be dealt with constructively and how do the interventions undertaken in the studied project contribute to this?

We start with a theoretical discussion of framing and cross-disciplinary research collaboration, then outline the methods used, and finally report and discuss the results.

A FRAMING VIEW ON CROSS-DISCIPLINARY RESEARCH

The Challenge of Cross-disciplinary Research

Cross-disciplinary knowledge is called for because real-world problems, such as water management, do not come in disciplinary-shaped boxes (Jeffrey 2003). A broad range of competencies is required to deal with these technically and socially complex issues. Putting together a good cross-disciplinary research proposal is not an easy task, however, and according to Sperber (2006), it can often result in a kind of "cosmetic interdisciplinarity," where the links between disciplines remain very superficial. In general, problems become apparent during project implementation when communication between disciplines is essential to achieve joint products. According to Bruce et al. (2004: 458), who studied interdisciplinary projects in the European Fifth Framework program, the need for interdisciplinary research, especially between natural and social sciences, is not met by the research community and "few studies [are] available on which to base policy recommendations for the support and management of interdisciplinary research." Cross-disciplinary research thus remains a very challenging endeavor.

Scientific disciplines distinguish themselves through different areas of interest, assumptions, priorities, vocabularies, methods, research practices, and communication media (associations, journals, conferences). These elements work together to constitute professional communities at the level of disciplines or sub-disciplines, into which researchers are socialized. In scientific organizations such as universities, which are traditionally structured according to disciplines, the latter can have strong effects on professional and even personal identity.

A number of different terms have been proposed to distinguish between levels of working beyond the borders of one's own discipline: multi-disciplinarity, inter-disciplinarity and trans-disciplinarity. For more background on these varieties see Bruce et al. (2004), Stokols et al. (2003) and Lawrence and Després (2004). We use cross-disciplinary research here as a more general and descriptive term embracing all meanings referred to above. One goal of our analyses is to find out how to facilitate cross-disciplinary collaborations aimed at integrating knowledge from different backgrounds.

Framing

In this paper, we analyze differences and collaboration between researchers from different disciplines from a framing perspective. The process of framing has been studied in such fields as environmental conflict (Lewicki et al. 2003), decision making (Tversky and Kahneman 1981), and negotiation (Putnam and Holmer 1992). A common denominator in the diverse uses of the frame concept seems to be that something, like a vague notion of a problem, an interaction situation, or a specific set of problem elements, can be understood in different ways, according to different frames, and that this holds different implications for what that something will be taken to mean. A frame can thus be considered a sense-making device (Weick 1995), adding meaning to a previously confusing or less meaningful situation or domain. When people from different backgrounds work together, they tend to frame the issues at hand in very different ways by defining differently "what this is all about."

The contexts where framing is relevant are frequently characterized by the active construction of meaning among multiple actors in "emergent organizational contexts" (Bouwen 1998), where common sense has to be made out of confusing or ambiguous situations. We adopt a discursive approach to framing (Dewulf et al. 2004), by focusing on how people define the meaning of an issue or how they negotiate the proper frame through the way they use language in their interactions with each other.

Framing in Cross-disciplinary Research

Cross-disciplinary research constitutes a context where multiple ways of framing the issues are likely. Each scientific (sub-)discipline orients its attention to certain phenomena, and takes a specific approach to conceptualize and study these phenomena. Each discipline thus maps a specific area, and maps it in a specific way (highlighting specific features of the area, using certain kinds of symbols, etc.). As Judge (1995) argues, these maps can be very diverse, overlapping, and difficult to reconcile, and yet everyone does not need the same map. The selectivity of a specific theoretical perspective or methodological procedure is what allows (sub-) disciplines to become very good at understanding a particular kind of phenomenon from a particular point of view. However, when a research project is set up where people from different disciplines work together, it is unlikely that these different orientations, methods, and conceptualizations will easily fit together.

Disciplinary background seems likely to influence how researchers make sense of a common issue. In a study of an interdisciplinary network on human impacts on ecosystems, Westley et al. (2003) found that a major problem was problem definition. It played a key role in the entry stage of the interdisciplinary collaboration, revolving around such questions as: who defines the nature of the problem, the scale of analysis (genetic, landscape, ecosystem), or the level of complexity (deterministic, stochastic, or chaotic)?

From a framing perspective, one can expect that researchers in cross-disciplinary collaboration will differ in the way they draw boundaries around an issue by including or excluding certain issue elements (different boundaries); in the issue element (s) they put into the focus of attention (different central concepts); and in which issue elements they use as encompassing and which they use as constituent elements (different overarching concepts) (Dewulf 2006). In this study, we focus on differences in issue framing in order to capture diversity at the level where it takes the form of divergent views on the issues to be researched.

The specific challenge posed by the confrontation of diverse frames of reference can be understood as ambiguity or the simultaneous presence of multiple ways of understanding a situation (Dewulf et al. 2005). This ambiguity can vary in intensity from a slight indistinctness, through confusion to tension and conflict. When differences in issue framing between disciplines emerge, people start negotiating these boundaries and conceptual arrangements in a process that can range from defending disciplinary positions to the creative construction of new transdisciplinary frames.

In general, dealing with ambiguity or different frames requires not doing away with the differences too quickly but exploring them in a constructive way (Dewulf et al. 2004). Exploring a difference means at the same time valuing and questioning both sides of the difference. This clarifies what the difference consists of, and can provide starting points for connecting the different frames. Bruce et al. (2004: 465) similarly argue that a good interdisciplinary researcher will have a high tolerance for ambiguity, and will refrain from reducing a problem to a limited set of dimensions, but rather take the time to explore the dimensions and boundaries of a problem. Exploring and connecting different ways of framing the issues is not just an intellectual task. The way issues get framed has important relational implications. Questioning our differences in how we frame the issues is a potentially risky activity for the way we relate to each other. A workable relationship has to be found between the different frames and the people using these different frames of reference (Dewulf 2006).

If faced with ambiguity, adding more and more information will likely only increase the ambiguity rather than reduce it. What is needed then are more —and more varied—cues and mechanisms that "enable debate, clarification, and enactment more than simply provide large amounts of data" (Daft and Lengel 1986: 559), in order to create meaning through discussion and joint interpretation. Rich communication media such as meetings and direct contact become more important than poorer

impersonal media such as formal information systems and special reports (Weick 1995: 99).

Framing has been identified as an important process in social learning (Bouwen and Taillieu 2004). Pahl-Wostl (2002) mentions the following framing-related aspects as important elements of social learning: construct a shared problem definition among a group of actors; build trust as a basis for critical self-reflection, which implies recognition of different perspectives and how they pertain to decision making; and reflect on assumptions and subjective valuation schemes. These elements also point to the importance of the quality of the interaction processes between people for fostering social learning (Bouwen and Taillieu 2004). For interdisciplinary research specifically, Bruce et al. (2004: 457) stressed the importance of consortium development, team building, and communication.

In the following section, we explain how we use this theoretical approach to study a large-scale cross-disciplinary research project, where we focus on three related research questions:

1. How do researchers differ in framing a central concept?

2. What challenges do framing differences pose for the project?

3. How useful are the interventions undertaken from a social-learning approach for dealing with these differences in framing?

METHODS

Multiple qualitative research methods were used in this study. With these methods, we do not aim at charting the frequency or intensity of certain phenomena throughout the project, but at better understanding them by studying a theoretically relevant sample (Charmaz 2000). The interviews, field notes, and evaluations were analyzed using the qualitative analysis software "Atlas-ti" (www.atlasti.com).

Based on interviews with members of the project consortium, we analyzed important differences in the ways adaptive management is framed in the project. We selected a diverse group of eight (of about 100) consortium members. Each interviewee came from a different research institute, and collectively, they represent the broad range of disciplines involved in the project. Half the interviewees are key people involved in the formulation and execution of the project, and the rest play a less central role in the project.

The interviews were conducted by one of the authors, in English, and were audio recorded. The interviewer asked open questions, such as: "What is your interpretation of adaptive management?" "Are you aware of other interpretations in the project?" and "How do these different interpretations affect the project?" These interviews provide a snapshot of some of the relevant frames and frame differences at a certain point in the project, namely at the first general assembly 11 months after the project started. These views may have changed since that time in response to the ongoing discussions in the project.

Because of the importance of language and vocabulary in the approach to framing we outlined above, we took a discourse analytical approach to analyzing the interviews (Wood and Kroger 2000), looking for differences in how the interviewees construct the meaning of adaptive management through the linguistic formulations they deploy (Edwards 1997). To this end, the interviews were fully transcribed. The frame difference dimensions reported in the results section were inductively derived from coding and comparing interviewees' statements related to adaptive management. Given the relatively limited number of interviewees, we do not claim to have identified all relevant frame differences in the project concerning adaptive management, or to have assessed their respective weight in the project. We do claim to have identified, on the basis of a comparative analysis of the 25 000 words comprising the text base of the interviews, four important dimensions of difference in the way adaptive management is framed in the project.

The authors also acted as participant observers within the project with respect to the cross-disciplinary process, taking notes during meetings about the ongoing interaction, and video- or audio-recording a number of meetings. These field notes and recordings were used as the basis for answering research questions two and three. Ten project meetings that occurred over the first 18 months of the project served as the basis for analysis.

Participatory evaluations and reflections were conducted on a number of occasions during or at the end of project meetings. In a feedback round, participants were given the opportunity to voice positive and negative feelings, experiences, or observations they had about the current or past meetings. These participatory evaluations and reflections were also recorded and transcribed, and used as data for research question three.

RESULTS

The structure of the results section reflects the set of three research questions. The first part analyzes different ways in which the central concept of adaptive management (AM) is framed in the project. The second part analyzes what kind of challenges this diversity of frames poses for the project work. The third part analyzes experiences with interventions in the project (organizing interactive workshops, facilitation, group model building, and using concrete case contexts) aimed at dealing constructively with this diversity of frames. Because of space limitations and the qualitative nature of the data, an important part of the supporting quotes and observations are discussed in Appendices I–III.

Different Ways of Framing Adaptive Management

From the interviews, we inductively identified four dimensions of difference in how the interviewees frame the central concept of AM: (1) the centrality of learning and experimentation in AM varies; (2) the role of uncertainty is framed differently; (3) AM can be understood primarily as adaptive capacity or as an AM regime; and (4) differences appear in specifying who adapts to what. We will discuss these dimensions one by one here, and illustrate our arguments with a table and quotes from the interviews in Appendix I.

The professional trajectory, in terms of disciplines, of most of the people we interviewed was more heterogeneous than we had expected (see Appendix I). The relation between AM frames and disciplines is, therefore, more complex than a one-to-one correspondence. This makes it hard to tell exactly how the frame differences we found are related to the disciplinary background of the interviewees. However, even between those researchers who have crossed the boundaries of different disciplines, we still found important differences in what AM means for the interviewees.

Learning and experimentation

Learning is a recurring aspect in the interviewees' statements about AM, but the importance of this learning process for AM is framed in different ways, ranging from central to peripheral. The nature of the learning process is also portrayed differently, specifically with respect to the central vs. limited role of experimentation (hypothesis testing through policy experiments). Finally, the interviewees differ in specifying who should be involved in the learning process.

Uncertainty

Another aspect in which framings of AM differ concerns the importance of uncertainty. Uncertainty is mentioned variously as an important aspect of AM, a marginal aspect, or not mentioned at all. Those who mention uncertainty do not necessarily mention it in a uniform way. One way of conceiving uncertainty stresses the unpredictability of the system. Another way focuses more on the different views of scientists and stakeholders about some key parameters of a change trajectory.

Adaptive management regime vs. adaptive capacity

The interviewees variously prefer to talk about AM or about adaptive capacity. The difference here lies in conceiving of AM as (1) a management system with an internal logic and a coherent set of elements (in the sense of "adaptive management regime"); or (2) a dimension that can be applied to management systems of very different kinds (adaptive capacity). The former seeks a general profile of AM systems in terms of coherence between a set of elements, whereas the latter looks for the adaptive merits of specific management systems in specific contexts.

Who adapts to what?

When interviewees use the terms "adapting," "changing," or "learning," they often specify additional aspects: (1) who or what is adapting, changing, or learning? (2) what is it that they adapt, change, or learn? and (3) in response to what do they adapt, change, or learn? The interviewees specify these aspects in different ways. With regard to all three aspects, both biophysical and social system

elements are mentioned. The actor responsible for the adaptation (aspect 1, e.g., the people) in one formulation, can become an external factor (aspect 3, e.g., changing preferences of people) in another formulation. In terms of framing AM, these differences indicate considerable divergence and potential for confusion in defining the boundaries of an AM system, by selecting those aspects that are inside the system (aspects that are adapting or being adapted) and others that are outside the system (aspects that the system adapts to).

In total, we could identify four dimensions of difference in how the concept of AM is framed in the project. Through the way the interviewees include and assemble elements in the way they talk about AM, they construct their understanding of AM, in which certain aspects figure as centrally important, while other aspects are not or are only marginally considered. Given the central place of the AM concept in the project, these differences have implications for project activities. The aspect of how to go about learning and the necessity of policy experiments—an issue that resonates with the AM literature, see, e.g., Lee (1999)— has important implications for conceptualizing the AM cycle, or for the kind of projects that are studied or set up in case studies. Different ways of looking at uncertainty can have implications for the range of water management strategies that are considered. The different assumptions implied by the notions of adaptive capacity vs. AM regime have implications for how the adaptiveness of a water management system is methodologically assessed. The way the question "who adapts what in response to what" gets answered, has important implications in terms of which aspects in a system are considered to be given, which aspects are considered as suitable for intervention, and who should take action. How a central concept is framed can thus have important implications for important project activities, such as the construction of a common conceptual framework, the choice of research of methods or the planning of interventions in the case studies.

Frame Diversity as a Challenge for the Project Work

Adaptive management is not the only concept that gets framed in different ways. Although we did not study these in detail, other core concepts like vulnerability, resilience, or uncertainty seem to generate a similar kind of ambiguity when researchers from different backgrounds interpret them from different perspectives. The different ways in which these central concepts are framed pose particular challenges to the project, in terms of mutual understanding and coordination. These challenges are illustrated in Appendix II.

1. *Very few concepts are self-evident to all participants.* It proves very difficult to find a meaningful starting point from which to construct a conceptual framework for the project. The difficulty here lies in finding words that make sense to everybody (even if this sense differs from person to person). Whichever concept is chosen, there are people who are unfamiliar with it or for whom it does not make much sense.

2. *Considerable confusion about concepts emerges in project meetings.* In some cases, when a meaningful concept is found, it is used by several people but with very different meanings or connotations. In other cases, very different concepts are used to refer to practices or phenomena that are very similar.

3. *The different concepts and meanings are not neutral.* From their socialization in specific scientific communities, people often feel strongly about which concept to use, especially if this concept is supposed to be used for a joint project task across different organizations or backgrounds. As concepts or ways of framing issues are often linked to specific communities, including or excluding a certain concept can have important implications for the position of people in the project, e.g., who gets a leading role for that part of the project, or who is considered the expert on a certain topic.

Dealing with frame diversity: experiences with interventions

In this context of frame diversity, integration is a highly needed but at the same time difficult process. Conflicts or the absence of communication can lead to fragmentation, where different frames remain disconnected and different groups continue to work with their own concepts and methods. A slightly

more desirable but not yet satisfactory outcome would be the dominance of one frame over the others. Opting for integrated computer simulation models, for example, would constrain the type of knowledge that can be included. In particular, the interpretive and qualitative approaches of the social sciences are very difficult to integrate in such an approach, which could lead to joint products but at the expense of excluding certain types of knowledge. The most desirable and yet most challenging approach would be a process of integration that leaves sufficient openness to include a wide range of different frames. It would imply that a diversity of frames can co-exist and be connected without resulting in fragmentation and thus in a collection of disconnected pieces of knowledge. This should be possible in a participatory and interactive process where genuinely new frames may be developed and explored. In the following section, we focus on a number of interventions that have been carried out in the project in order to stimulate the exploration, connection, and integration of different frames.

In the absence of clear guidelines or established practices for cross-disciplinary work, a number of experiments in social learning (Pahl-Wostl 2002, Bouwen and Taillieu 2004) are being tried out in the project, to deal with the ambiguities provoked by the divergent frames and to foster constructive ways of connecting knowledge from different backgrounds (Pahl-Wostl 2006). The methods employed draw on the fields of participatory stakeholder processes, integrated assessment and management, multi-actor collaboration and organizational development. We discuss and evaluate these attempts in the following subsections.

Organizing interactive workshops

A general approach in the studied project is to organize interactive workshops to exchange ideas during face-to-face discussions, to develop a common language and a basis for understanding, and to decide on courses of action. As we argued above, connecting frames is a challenge on both the content and the relational levels. Content can be transmitted through other means of communication as well, but relational connecting is much more powerful in face-to-face interaction than through more impersonal means of communication.

From the participants' evaluations and our observations, which are documented in Appendix III, we can conclude that the participants generally valued the workshops, and that they especially valued the more interactive parts of the workshops, like working in small break-out groups. The latter were evaluated as more productive and contributing to a good atmosphere among the participants. Open and mutual questioning, an important aspect of exploring different frames, seemed to become possible in these workshops, especially in the smaller and more interactive meeting environments. As a downside, participants mentioned the high investment of time and resources that workshops require, and the problem of the ever-changing constellation of people at workshops—this can considerably slow down progress in relational connecting and learning to work as a group.

Facilitation

In the interactive workshops, the session format was mostly presentation followed by a question and answer session. This generally does not stimulate a lot of discussion. It is not easy for presenters to take up the double role of presenting a lot of content and chairing the meeting. Presenting calls for clear explanation and information flow from the presenter to the audience. Chairing the meeting calls for stimulating participation, checking comprehension, following up on comments, and explicating (and checking) the goal of the meeting and what we expect as outputs. It is not an easy job to combine both these roles in one person, and presenters seemed to have difficulties with it, resulting in situations where the frame of the presenter dominates the meeting.

Some of the interactive workshops were facilitated by qualified project members. In general, the complementary roles of presenting vs. facilitating worked well. The presenter can concentrate on the subject, while the facilitator is in touch with the audience, prepares the upcoming interaction, and invites and structures the discussion. This proves very comforting for the presenter. However, some people succeed in fulfilling both roles, by combining their scientific understanding with process skills. Even in an informal setting, they can thus obtain high credibility and acceptance by the group. We document this in Appendix III.

Group model building

The project coordination team decided to adopt a participatory model building process supported by a binding yet flexible graphical notation, namely Unified Modeling Language (UML). This would support the construction and understanding of a common conceptual framework, in which graphical representations are combined with narratives that document the line of argument.

From participant evaluations and our observations, which are documented in Appendix III, we can draw the following conclusions. Using UML in group discussions helps make mutual assumptions explicit, because everybody attempts to translate his or her concepts into a common language. In selecting aspects, labeling them, drawing the relations and labeling the relations, differences between participants' frames can emerge and can be discussed. Creating the diagrams also helps identify where knowledge of a system or process is incomplete. An advantage of UML is that it does not rely on the often implicit and possibly diverging meanings of the visual aspects of the diagram. The disadvantage is that people may still read those meanings into the visual aspects of the diagram and make diverging conclusions.

Working with UML as a tool for documenting and exchanging knowledge can be interpreted with Wenger's (1998) participation–reification concepts. Participation, meaning here involvement in the development of knowledge, needs reification, e.g., diagrams (or papers or reports) to store and "transport" this knowledge. But reifications always need participation: people need to be willing to learn and to use the new language and to work with it, otherwise the diagrams remain meaningless. This learning process will have to be partially redone every time a broader group is expected to work with the new language.

Using concrete case contexts

Using concrete case contexts in an interdisciplinary environment can be done for a number of reasons. Explaining or illustrating theoretical points with examples from a jointly available case context makes them more understandable for others, and can make explicit important differences in understanding.

In order to deal with different frames, some kind of anchor point is needed that allows working constructively with the diversity. Concrete case contexts can provide this necessary common ground when different theoretical approaches have to be dealt with, because they provide a kind of anchor point for keeping the discussion focused and the exploration of different views going. This requires that the specific case that is used to focus the discussion is sufficiently known by the different participants.

As we illustrate with observations and participant evaluations in Appendix III, using concrete case contexts was found to be motivating and helpful for clarifying concepts. When the level of detail and complexity of a case situation is too high to work with, simplified or stylized representations of case situations were used with apparently positive results. Asking researchers from different backgrounds to apply their respective concepts and methods to a concrete case description that is available to all participants, was evaluated as helpful for eliciting and understanding the different frames of reference.

Schön and Rein (1994) have similarly argued that "situated" frame reflection is needed for dealing with frame conflicts in policy controversies. They claim that "when policy controversies are abstracted from the situations in which they arise, as in academic discourse, they are removed from the pace and pressure of the policy arena, but they exist in a kind of vacuum where it is hard to imagine how they might ever be resolved" (Schön & Rein 1994: 176). As a strategy for resolution, they propose reflecting on the involved frames with the aim of getting to a pragmatic solution in a specific context. Therefore, the role of the seven case studies in the project could be crucial in fostering cross-disciplinary outcomes.

DISCUSSION AND CONCLUSIONS

We started by identifying the necessity of cross-disciplinary research collaboration for achieving a better understanding of how human and natural systems are dynamically linked. Single disciplines are generally ill-equipped to deal with issues that are both technically and socially complex and interdependent. On the other hand, genuinely cross-disciplinary research appears difficult to put into practice.

We analyzed cross-disciplinary research collaboration from a framing approach, focusing on the different frames of reference that researchers use to make sense of the issues that they want to study jointly. From analyzing interviews with members of a large-scale research consortium on adaptive water management, we inductively identified four dimensions of difference in the way the researchers framed the central concept of AM: (1) they framed the centrality of learning and experimentation to AM in different ways; (2) they framed the role of uncertainty differently, in terms of unpredictability or in terms of different views; (3) they framed AM either as a management system with a coherent set of elements ("regime") or as a dimension that can be applied to management systems of very different kinds ("adaptive capacity"); (4) in specifying "who is adapting?" "what is that they adapt?" and "in response to what do they adapt?" the interviewees' answers diverged significantly.

Some of the challenges of cross-disciplinary research could thus be better understood as dealing with the ambiguity and tension provoked by the simultaneous presence of multiple ways of framing or understanding a situation or issue (Dewulf et al. 2005). By analyzing meeting observations, it appeared that very few concepts are self-evident or neutral for all project participants. Considerable confusion about concepts emerges in project meetings because either the same concept is used by several people but with very different meanings, or conversely, very different concepts are used to refer to practices or phenomena that are very similar. A cross-disciplinary research approach calls for integration of different kinds of knowledge into a new framework but the aforementioned challenges indicate that this is not a straightforward process.

A number of interventions were tried out in the project from a social learning approach (Pahl-Wostl 2002, Bouwen and Taillieu 2004), in order to foster constructive ways of connecting knowledge from different backgrounds. It is too early to make final judgments about whether the approaches chosen will be successful, or if the considerable investment of time by project participants in joint activities will result in innovative products that would not have been possible without this investment. Nevertheless, on the basis of participants' evaluations and our own observations, we tried to assess the impact of four types of interventions during the first 18 months of the project.

- The participants generally valued the workshops, and especially the more interactive parts, e.g., working in small break-out groups, which were evaluated as more productive and contributing to a good atmosphere among the participants. They allowed for open and mutual questioning, an important aspect of exploring different frames.

- Some of the interactive workshops were specifically designed and facilitated by qualified project members. In general, the complementary roles of presenting vs. facilitating worked well and allowed for more opportunities for open discussion across different frames.

- Using participatory model building in UML helped make mutual assumptions explicit and the differences between participants' frames more visible and understandable.

- Using concrete or stylized case situations as a way to deal with diverse methods or theories, allowed participants to use the case situations as a common ground to which the various frames could be connected.

As we have argued, cross-disciplinary research requires dealing with diverse frames, which often take the form of tacit understandings about how disciplines or theories select, focus, and embed aspects of the world, and how they articulate these issues in a specific vocabulary. If we try to reason a step further from these findings and similar ones (e.g., Dewulf 2006), we can suggest a hypothetical process of optimal steps in dealing with cross-disciplinary frame differences.

1. *Get to know each other's frames.* A first step is to be confronted with the different kinds of knowledge others contribute.

2. *Acknowledge differences.* This requires paying attention to differences and not acting as if there were none.

3. *Incorporate other concepts into your own framing.* A first and perhaps inevitable step in understanding other frames is to translate

them into your own terms. This does not do justice to the full richness of the knowledge, but is probably necessary as first approximation (just as translating words is often a necessary intermediary step when learning a foreign language).

4. *Explore and work with the differences.* A further step is to mutually explore the different views so that each can understand the other's view in its own terms, and thus find out where the frames are incompatible and where they provide complementary contributions.

5. *Forge new frames.* As a way of integrating different frames, often a new vocabulary has to be created that is able to carry the new and jointly created meanings and knowledge.

As was evident from the results reported above, these kinds of processes set high requirements in terms of interaction and learning between researchers. Further research is needed to assess whether this hypothetical process leads to the expected results in terms of frame connection and integration, and whether the interventions we reviewed can be fine-tuned to facilitate this process specifically.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol12/iss2/art14/responses/

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APPENDIX 1. Different ways of framing "adaptive management": quotes from the interviews

In this appendix we present quotes from the interviews on adaptive management (AM) to illustrate and support the four dimensions of frame difference we discussed in the main text. We use I1 to I8 to refer to the eight interviewees.

When we asked interviewees which scientific discipline they belong to most interviewees were not able or didn't like to label themselves in terms of one specific discipline (I1, I2, I3, I5, I6). They described different disciplines they had been working in over the course of their career or they mentioned a field that is interdisciplinary in itself (e.g. integrated assessment, management sciences, integrated water management). Some of them (I2, I6) framed their background as consisting of an initial field of education and several fields of interests. Although most interviewees had a background characterized by multiple disciplines they can hardly be considered generalists. There still was a clear difference in background and in the focus of their research.

Text analysis of the interviews led us to the identification of four dimensions of difference in the way the interviewees frame AM. These dimensions are presented with illustrative quotes in the following table and then discussed one by one.

	Learning and experimentation	Uncertainty	Adaptive capacity	Who adapts to what?	Disciplinary background
I1	"AM is learning to manage by managing to learn"	"manage complex systems in an uncertain world by simply being able to adapt to new insights"	-	"a system" / "people" <adapt> "management decisions" <in response to> "new insights" / "changing management objectives"	Chemistry; Molecular biology; Environmental Physics; Integrated assessment; Social sciences
I2	"AM to me is, has a lot to do with learning, because it was developed in response to failure to learn" "And we then try to make everybody ... part of an experiment" "the policy now is the test of your best hypothesis"	-	-	"academics" / "policy makers" / "people in business" / "people without any training" <learn> "together" <in response to> "failure to learn" / " catastrophes"	Systems Ecology; Cognitive Psychology
I3	"I deeply believe that, the social change dimension of AM ... can be reached only through experimentation"	uncertainty with respect to (1) "where we are" (2) "where we want to go", (3) "which path to follow" and (4) "monitoring"	-	"social system" <adapts> (unspecified) <in response to> "change"	Computer Science; Management Sciences
I4	-	"In relation to uncertainty you have an adaptive capacity which is able to accommodate surprises"	"adaptive capacity ... is actually the most important goal, the most important thing you should look at"	"stakeholders organized as a coordinated group" / "the system" <adapt> (unspecified) <in response to> "a structural change in external conditions" / "changing of the preferences of your people"	Agricultural Engineering; Hydrology
I5	"definitely learning and learning together" "the learning aspect, where you explicitly try to engage in experiments and learn from that"	"you want to deal with uncertainty ... you want to prepare yourself for different futures"	"you want to strengthen the adaptive capacity of the system"	"both ecosystems and actors or people" / "scientists together with stakeholders" <adapt> "water management strategies" / "river flow" <in response to> "enlarged scope of situations that might happen to you" / "change"	Water Resources Engineering and Management; Environmental Sciences; Experimental Physics

(con'd)

I6	"It is a process of exercising, and act then learn, then learn some more, then act again"	-	"we need to do that by increasing the ability to adapt, so adaptive capacity comes into the language quite quickly"	"a hundred people together across two dozen stakeholders" <change> the system <in response to> "unfolding risks as they occur"	Political ecology; Social geography
I7	"It basically adds a sort of a learning aspect, a learning component to IWRM"	"create some sort of responsiveness within your system to react in a better way to things that might happen in the future"		"the stakeholders" <adapt> "strategies or actions" <in response to> "scenario's" / "things that might happen" / "issues challenging our management"	Management Sciences
I8	-	"The events they, you can't predict them. And you also don't know how the frequency and the magnitude of this event are developing. And so you have to create a management system that is able to react to these events"	-	"management system" <adapts> (unspecified) <in response to> "events and change in these events" / "difficult situations"	Political sciences; Social sciences

Learning and experimentation

Learning is a recurring aspect in the interviewee's statements about adaptive management (AM). For one interviewee (I7) the learning cycle is what sets AM apart from IWRM, and thus a key aspect in defining AM. Four others (I1, I2, I5, I6) also mention learning as a key element of AM: "AM is learning to manage by managing to learn" (I1); "AM to me has a lot to do with learning, because it was developed in response to failure to learn" (I2); "definitely learning and learning together" (I5); "It is a process of exercising, and act then learn, then learn some more, then act again" (I6). Three interviewees do not refer to learning in their statements about AM.

Interviewees differ in the extent to which they conceive this learning process as consisting mainly of hypothesis testing through policy experiments. Five interviewees mention experimentation, and for two of them, learning pretty much means experimentation: "the learning aspect, where you explicitly try to engage in experiments and learn from that" (I5); "it is a cycle of learning, assessing a problem, then posing hypotheses ... the policy now is the test of your best hypotheses" (I2). The other two (I1, I7) mention experimentation as an additional possibility but a very crucial or viable way of learning in AM. Interestingly, one interviewee (I6) mentions learning but not experimentation, and another (I3) mentions experimentation without learning, indicating again that learning and experimentation are not used as synonyms among the interviewed researchers.

Interviewees differ also in whether they specify the actors of the learning process, or who should be involved in the learning process: e.g. mainly the responsible water managers; or the whole group of scientists, policy makers and stakeholders; or scientists and stakeholders.

Uncertainty
Two of the eight interviewees do not refer to uncertainty when asked about their definition of AM. Of these six, one mentions uncertainty only as a marginal aspect (I7), and the rest do include uncertainty as an important aspect of what AM means. However, they do not necessarily mention it in a uniform way.

The interviewees mentioning uncertainty as an important aspect of what AM means, mention it in different ways. The following interviewees stress the unpredictability of the system as follows:

- I1 links uncertainty to the complexity of the systems and the limits to predictability.
- I4 links uncertainty to stochastic drivers of the system, which generate surprises.
- I8 links uncertainty to the unpredictability of events, their frequency and magnitude.
- I5 links uncertainty to different possible futures.

In addition I3 identifies uncertainty with respect to (1) where we are, (2) where we want to go, (3) which path to follow, (4) monitoring. He focuses on uncertainty as a consequence of different views between scientists and/or stakeholders about some key parameters of a change trajectory.

Adaptive management regime versus adaptive capacity
Although the expression used in the interview questions was "adaptive management", three interviewees (I4, I5, I6) draw strongly on the concept of 'adaptive capacity' for explaining their views. Only one interviewee spontaneously uses the term regime while explaining adaptive management.

Two interviewees (I4, I6) claim the term adaptive capacity to be better suited for the project. I4 calls it "the most important goal, the most important thing that you should look at". I6 stresses adaptive capacity as "the ability to adapt" and contrasts this with the notion of a 'regime', because "that seems to imply ... all sorts of assumptions about institutions and so". He argues, for example, that "you can have very effective adaptive management regimes that are completely hierarchical or oligarchical".

Who adapts to what?
When interviewees use the terms ‘adapting’, ‘changing’ or ‘learning’, they often specify additional aspects: (1) who or what is adapting, changing or learning?; (2) what is it that they adapt, change or learn; and (3) in response to what do they adapt, change or learn? The interviewees specify these aspects in different ways. In the above table, we represented these three elements per interviewee, and combined them with the specific terms that the interviewee uses as operators (between < >).

(1) Often the first question is left unanswered in how they talk about adapting, but when specified, the following kinds of things are said to be adapting, changing or learning: 'the system', 'the people', 'the ecosystem', 'the stakeholders', 'scientists and stakeholders' or 'the management system'.

(2) The second question is also left unanswered in many cases, but 'management strategies', ‘management decisions’, 'river flow' and 'the system' are mentioned as things that are adapted or changed.

(3) With respect to the third aspect, the following things were mentioned in response to which adaptation, change or learning occurs: 'change', 'changing management objectives', 'new insights', 'structural change in external conditions', 'new external situation', 'external change', 'changing preferences of the people', and 'flood disasters'.

Interestingly, with regard to all three aspects both biophysical ánd social system elements are mentioned – the general 'system' mostly stands for both. Starting from the following questions: (1) who

or what is adapting, changing or learning?; (2) what is it that they adapt, change or learn; and (3) in response to what do they adapt, change or learn?; we can try to identify the possibilities by structuring the three aspects into either biophysical or social system elements. Thereby we get the following eight combinations:

1. the biophysical system adapts the biophysical system in response to biophysical changes (e.g. complex adaptive ecosystems under climate change)
2. the biophysical systems adapts the biophysical system in response to social changes (e.g. complex adaptive ecosystems under human-induced stress)
3. the social system adapts the social system in response to biophysical changes (e.g. learning to live with water)
4. the social system adapts the social system in response to social changes (e.g. the government starts subsidizing drinking water service for single parent families)
5. the social system adapts the biophysical systems in response biophysical changes (e.g. creating floodplains in response to extreme events)
6. the social system adapts the biophysical system in response social changes (e.g. making polders in response to need for arable land)
7. the biophysical system adapts the social system in response to biophysical changes (e.g. replacement of species due to climate change which may result in long-term trends in water availability)
8. the biophysical system adapts the social system in response to social changes (this seems logically impossible)

This list serves as a thought experiment about possible meanings of adaptation. The broad range of possibilities does not even take into account that parts of a subsystem can change other parts of the same subsystem (e.g. one part of the social system can change another part of the social system). This illustrates how adaptation can be understood in very diverging ways.

APPENDIX 2. Frame diversity as a challenge for the project work: observations

On many occasions researchers in the project were confronted with the different ways concepts are framed. In trying to understand new concepts, or concepts they are not familiar with, people interpret them differently. These differences are often based on their disciplinary background and the research tradition they are connected with. The result is considerable confusion in project meetings, which makes mutual understanding and collaboration difficult.

This challenge has been expressed by many researchers in the project with comments as:

- *"In the project we have very little shared understanding."*
- *"How can we get beyond the jargon?"*

An important number of concepts that were used in the project proposal and at the initial project meetings were unfamiliar for a part of the project members. A participant in the project kick-off meeting, for example, reported that she was unfamiliar with the "mental model" concept, which was used by participants with a psychological background, while others didn't get the meaning of "code" used in the sense of a piece of software programming by participants with a background in computer modeling.

Often the same concept was used by several people but with very different meanings or connotations, as we illustrated in our analysis of adaptive management. Another good example is the 'regime' concept, mainly used in the sense of a water management regime. However, for the political scientists in the project, 'regime' and certainly 'regime change' means something very different, and for people with a water management background 'regime' can also refer to the flow regime of a river.

On the other hand different concepts are used to refer to very similar practices or phenomena. An example of this are the various concepts used to refer to interactively constructing a conceptual model – a method that has been used and adapted in different disciplines and is variously referred to as 'causal loop diagramming', 'group model building', 'causal mapping' or 'Bayesian network analysis'.

Hereafter, we illustrate in more detail how different ways of framing a concept played out in two episodes from two different project meetings.

Episode 1. Protocols for vulnerability assessment

In one of the workshops different protocols were offered to assess vulnerability in the cases. The protocol that was presented on the first day was based on work in the social sciences. It was an exercise in collecting qualitative data, defining boundaries of exposure units and rating vulnerability based on different kinds of criteria. At the end of that day some participants looked very worried. One of the case study leaders said not to feel capable of bringing this approach to the stakeholders. Most participants were from a quantitative modeling background and had difficulties in working with qualitative data and in assessing their validity. This piece of conversation, reconstructed from meeting notes, can illustrate this kind of challenge. At the end of this sequence one participant frames filling in a table with qualitative data as a 'game', while the presenter stresses that not the narrative in itself is important, but the analysis is.

- *Presenter: "Collect the narrative of the basin, no analytical data but the story. Go back to the history of the basin."*
- *Participant: "Who can tell which data are really necessary?"*

- *Presenter: "Rather qualitative data"*
- *Other participant: "I need guidance to fill in the table, I hate games."*
- *Presenter: "The narrative without analysis is inappropriate."*

Those unfamiliar with qualitative research methods struggled also with the following aspects. Defining the boundaries of the river basin and of exposure units was considered very arbitrary and thus biased. They became aware that the vulnerability table is filled in from one particular perspective. And the way vulnerability was rated, was called subjective. The presenter's comment that "making categories is always a kind of judgment" didn't really comfort them. They truly wondered how one can deal with the 'bias' caused by one's own perspective.

Episode 2. Bayesian network tool

In the course of a meeting the 'Bayesian network tool' was presented as a participatory tool. Social scientists involved in participatory processes questioned the presenter: "What is your network consisting of? Is it a social network?" It was clarified that the 'network' concept did not refer to a network of people (as is often assumed in social science) but was referring to the elements of the model and the cause-effect relationships among them. The role of the stakeholders also became clearer. They were involved in the modeling process to bring in local knowledge about the system to be modeled and individual or group perspectives.

Presenter: "Stakeholders bring their values and views to the network."
Participant: "What happens when their views differ? Do you start a process to create something in common or do they continue to exist as different views?"
Presenter: "Yes, that's life. The Bayesian network shows what the consequences are if you take one perspective and then when you take the other one."

The qualification 'participatory' didn't refer to stakeholders acting in a negotiation process to connect different perspectives (as some of the participants were assuming), but rather to involving stakeholders as a source of information.

APPENDIX 3. Dealing with frame diversity: evaluations and observations

Four different kinds of interventions in the project have been observed from a social learning perspective. We used participant evaluations and our own observations during these workshops to assess the impact of these four kinds of intervention. How do they enable to deal with the ambiguity provoked by frame diversity? And do they foster constructive ways to connect knowledge from different backgrounds?

Organizing interactive workshops: evaluations and observations

To assess the impact of organizing interactive workshops, rather than relying on written communication, we have assembled evaluations and observations from 6 project workshops. We report the results thematically hereafter.

Participants in interactive workshops valued them for several reasons:

- *"People could see each other face to face"*
- *"Communication and work in the break-out groups, and small internal meetings"*
- *"We have communications that would not be possible through e-mail, e.g. integration"*
- *"People got to know what they can expect from each other"*
- *"People recognized where they fit in, they became aware of linkages"*
- *"We have tangible and intangible outcomes, like working with the group, which we will realize later"*

In this sense, the workshops contributed to the relational side of connecting the people using the different frames: getting to know each other and mutual expectations, finding a place and a role in the project, starting to work as a group.

That the participants referred to the more interactive parts of the workshops as the more fruitful ones adds to this picture. Working in smaller groups was experienced as the most helpful to explore and define new concepts.

- *"Break-out groups were the most interesting and useful discussions, the most interactive"*
- *"We need longer slots for small productive groups"*
- *"Smaller groups were really positive, working on a clear product keeps you focused"*
- *"In the discussion we were questioning a lot of things, ..., we were questioning each point we elaborated before, generating new ideas"*
- *"Products were better because of the small groups, I had fun moments in the break-out groups"*

Also working with an open format ("market") to stimulate intensive interactions was valued:

- *"At the end of the market, I felt that something started to happen, I didn't want to get back to the plenary"*

From our observations it was also clear that small group activities during the workshops generated much more lively and in depth discussions than the usual presentation plus questions format.

According to the experiences of the participants, open communication contributes to the value of interactive workshops.

- *"I experienced as positive that everybody is very willing to listen to each others views and opinions"*
- *"Very good atmosphere, trial and error approach without feeling bad about it is very constructive"*

One of the participants reported that his way of framing adaptive systems was changed through a workshop ("my mental model about adaptive systems evolved"). From our observations, an interactive discussion episode during a workshop about the difference between current water management, integrated water resources management and AM allowed an exploration and redefinition of these concepts among the participants in ways that would be very hard to achieve through other means.

As a downside, frustration was also expressed with respect to the high investment of time and resources that workshops require. It seems like there is never enough time in a workshop:

- *"It is not possible in one meeting"*
- *"There was not so much time as I expected"*

Furthermore, the important relational effects a workshop can have, impacts only the people who were there, and the results that are generated depend on the group of people that went through that process together.

- *“At the same time I feel a bit uncomfortable about randomness: the composition of the group does matter in what we have as result, we should be very conscious about it”*
- *“I had a low moment this afternoon, because it seems like every meeting is starting anew”*
- *In this vein, a number of participants experienced as problematic that "people come in and jump out" or are “concerned about earlier leaving”.*

Facilitation: evaluations and observations

Evaluations and observations from 4 project workshops served as a basis for assessing the impact of facilitation.

At the end of the kick-off meeting of the project, the difficulty of taking the double role of presenting a lot of information and at the same time facilitating the discussion was identified in a debriefing between the organizers and observers of the meeting. Presenting calls for clear explanation and information flow from presenter to public. Facilitating the meeting calls for stimulating participation, checking comprehension, following up on comments and explicating (and checking) the goal of the meeting and what we expect as outputs. It’s not an easy job to combine both these roles in one person, and presenters seemed to have difficulties with it.

This was one of the reasons why a next workshop was specifically designed and facilitated for exploring the different frames of reference of the participants and dealing with them in constructive ways, in order to reduce confusion and increase mutual understanding. This took the form of inviting participants to prepare a 2-slide presentation on their view of the workshop’s central topic. These presentations were then given at the start-up of the workshop. In this way, a number of differences in conceptions came to the fore, which might otherwise have remained implicit. The way this phase of the workshop was designed and facilitated allowed people to better understand the background of the others around the table and use that knowledge throughout the further discussions. Comments of the participants when evaluating the workshop show they valued the influence of the facilitators on the design of the workshop

as well as the role they took during the workshop.

- *"The moderation was very good, everyone was able to look beyond one's own perspective in the open break-out groups. We can now position ourselves better."*

- *"The complementary roles of presenting versus facilitating worked well."*

By contrast, in another workshop where only the presenters' role was taken and important differences in interpretations and views between the presenter and the other participants emerged but remained unaddressed, the following comment was given at the end of the day: "Did we have to meet for this ? We could have read this. I expected more guidance."

Sometimes one person is able to fulfill both the roles of participating and facilitating. In that case process skills are combined with a good scientific understanding, the latter increasing the credibility of the facilitator. This situation was present in a workshop that was organized to change the dynamic of a rather polarized discussion between two research groups. A third group of researchers was brought in. They had their own alternative approach and thus contributed to the discussion at the content level. At the same time interventions on the procedural level were made by this third party, leading to shared action plans and thus improving the interaction process. The example shows that the facilitator's role can be taken in an informal way if this is accepted by the group. One of the group members confirmed the effectiveness of this setting: *"So in the meeting yesterday we brought in X, who hadn't been part to that, I mean, been part of some of the discussions. A new one can and could immediately see how it could work, could see a role for themselves. The rest of us were willing to allow this."*

Group model building: evaluations and observations

To assess the impact of group model building, we analyzed observations and evaluations from the 2 first project workshops where UML was intensively used for building up joint conceptual frameworks.

Several graphical notations for the graphical visualisation of the framework were discussed at project workshops and bilateral meetings. UML (unified modelling language) was finally adopted as the modelling notation for the project framework on transition towards AM. UML is not a running model itself. It is rather a notation system that allows documenting or specifying knowledge about objects, relations and associations, workflows and processes, responsibilities, information flows, interfaces, etc. UML supports different views or frames on the same part of the world. All 'views' or diagrams share the same terminology and their level of detail depends on the degree of information that is required to understand a certain problem. Due to this approach a diagram is a view into a model presented from the aspect of a particular perspective (e.g. a stakeholder), it provides a partial representation of the system, and it is semantically consistent with other views.

Using UML in group discussions helps to make mutual assumptions explicit, because everybody attempts to translate his or her concepts into a common language. In selecting aspects, labelling them, drawing the relations and labelling the relations, differences between participants' frames can emerge and can be discussed. It also helps to keep the attention focussed on the developing diagram and it results in a tangible output of the discussion (one or more diagrams).

- "*making these diagrams is useful to access knowledge that's in someone else's head*"

- "*with the diagrams you have to become more precise*"

- "*very useful for the discussion because it focuses the discussion on a visual image*"

- "*we were talking and talking until now but now we have a clear result*"

- "*it is positive that each of the groups made good products*"

Making the diagrams helps to identify where knowledge of a system or process is incomplete. Information about some elements or links may be missing.

- *"I think it helps to identify knowledge gaps, to see where our description is incomplete"*
- *"It was interesting to see the bits of information that were lacking"*

It's important to embed the making of diagrams in a larger process and clarify the goals of making them (knowledge representation, integration, facilitating discussions, ...). Otherwise, people may not see the point of making the diagrams, or at the other extreme, people may start using UML indiscriminately. Keeping track of the developed UML diagrams and limiting their number by prioritizing will not be an easy task.

- *"The first big discussion was: how we can use these diagrams or why do we need them in the process, and if we now start with this are they really used later"*
- *"we should be clear about what we want to get out of it from the beginning so that we don't make a diagram for the sake of the diagram"*
- *"we should be very critical about which ones we make"*

In terms of finding a mutually workable representation, the top level representation (the "matrix") itself may be the biggest challenge, since this captures world views on a high level of abstraction. In some cases, starting from representations of concrete subsystems may be easier (e.g. starting from the most important issues in a specific case).

- *"We spent much time on the matrix and which cell was the most relevant for us. We ranked all the cells independently, and there were very different perceptions"*

A workable equilibrium between technically correct UML and easily understandable UML should be found. The best diagrams may be those where "UML-experts" watch the formal correctness, while "UML-laypersons" assure it is easily understandable for non-experts as well.

- *"formally correct UML diagrams are not necessarily the most easily understandable ones"*
- *"we need set quality standards, if not we are prone to ambiguities in interpretation, we need quality check"*

A characteristic of UML as a formal language is that the visual lay-out of elements and relations in a specific view is technically meaningless: as long as the entities, attributes and relationships remain the same, you can rearrange the visual representation as you like without affecting what it means in UML. People are used however to derive meaning from the visual aspects of a diagram (above-below, left-right, close-distant, ...), and this may affect the meanings that are connected to the diagram. The advantage is that UML does not rely of these often implicit and possibly diverging meanings of the visual aspects of the diagram. The disadvantage is that people may still read those meanings into the visual aspects of the diagram and make diverging conclusions.

A general concern with respect to the integration of different theories into a conceptual model, is the difficult distinction between (1) connecting concepts that represent different parts of reality, and (2) connecting concepts that categorize differently the same part of reality. The problem is that our concepts to some extent define what we take to be the reality. The more cautious approach may be to allow for parallel representations of parts of reality where or when necessary (different ways of framing the issue), and try to identify overlapping parts and look for complementarities where possible.

Using concrete case contexts: evaluations and observations

To analyze the impact of using concrete case contexts we used evaluations and observations from 3 project workshops. The third workshop was explicitly designed to profit as much as possible from the use of concrete case contexts.

The idea of using concrete case contexts when confronted with diverging theoretical frameworks, is that the meaning of a concept, theory or method can be easier understood when we look at specific contexts and illustrate there what the concept means. The concrete case context can then provide the necessary common ground to discuss concepts that come from different backgrounds.

In one of the facilitated workshops, case presentations were deliberately used for clarifying concepts related to AM. Two people who were each very familiar with a specific case, prepared an overview of the situation. The other participants were then invited to draw upon these inputs, and the presenters, to clarify and discuss the various concepts. A number of evaluations which were voiced during and at the end of the workshop referred to this approach, evaluating it as motivating and helpful.

- *"we need examples for understanding what we mean, we may not have enough case studies in the project"*
- *"the early exemplary case approach was very helpful, it was good to have case study people around"*
- *"the case example taught me about complex adaptive systems, I understood better the meaning of transition as a natural process versus change as a result of deliberative actions"*
- *"the break-out groups on a very concrete case generated a lot of attention and energy, focusing on a concrete reality was enough to keep on contributing"*
- *"the case studies as background were useful, but could have been used even more"*

However, concerns were also raised that scientific rigor may suffer when focusing on concrete cases.

- *"NeWater is an Integrated Project and needs to develop integrated concepts first before applying it to cases. Otherwise the quality of generalizable scientific insights will suffer."*

In another project workshop, efforts to integrate different approaches for vulnerability assessment didn't succeed. A direct comparison of different research methods seemed to be too sensitive. Probably the position of both research groups as well as the differing contexts in which these methods have been applied, made a comparison very difficult. The decision to choose one "stylized situation" on which the different approaches under investigation would be applied, created some commonality to easier interpret the differences in the results. This approach uses case contexts not in their full complexity and detail, but through a simplified representation. The stylized situation still refers to a specific situation in a specific case and is thus different from an abstracted theoretical model.

In the studied project, very different frames about uncertainty exist among scientists coming from different research traditions. In a workshop on uncertainty, concrete situations in which uncertainty was experienced by water management practitioners were collected through dialogue sessions with decision-makers in several case study contexts. By means of a few open questions they were invited to tell about specific uncertainty related situations they had experienced, and these were summarized as short stories or vignettes. The most striking illustrations of different types of uncertainty were selected from the stakeholder dialogues and presented at workshop among scientists. Scientists from different fields discussed in break-out groups how they would deal with the uncertainties in specific case situations. In the discussion participants could easily refer back to these case situations, which provided a common focus for the group discussions. The cases allowed them to present and explain better their concepts and

the approach they would take by applying them to the case examples. In the evaluations of this workshop, participants referred to this way of working in positive terms.

- *"it was positive that it was linked to practical examples, so we could combine the different approaches"*
- *"it was quite good to work very concretely, in small groups"*
- *"it was very interesting to see that you get other views on the vignettes, from very different perspectives"*

5 INTERDISCIPLINARY KNOWLEDGE INTEGRATION THROUGH GROUP MODEL BUILDING WITH UML

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ABSTRACT. As part of the inquiry into managing the knowledge integration challenge in an interdisciplinary research process, we investigated the process of Group Model Building (GMB) and, more specifically, the role of Unified Modeling Language (UML) in this process. An analysis of group interaction reveals several dilemma's in the process of knowledge integration, which can be grouped in three overarching dilemma's: 'simplicity versus complexity', 'constraining versus containing' and 'defining versus refining'. As group members take different positions with regard to these dilemma's, these represent sources of tension and potential 'stuckness' of the group model building. We suggest that early recognition and corresponding management of these dilemma's may facilitate knowledge integration.

5.1 Knowledge integration in cross-disciplinary research

Over the last decades, policy-makers and researchers alike have become aware that key questions related to the sustainability of human activities on Earth cannot be answered within the confines of scientific disciplines. Attempts to address such vital questions have resulted in an increasing amount of research across the boundaries of traditionally separate fields of study. Newell and his colleagues (2005, p. 299) point at the creation of new subjects (including e.g. human ecology and environmental economics) as well as an extended "disciplinary reach" of existing subjects. The interfaces with other scientific disciplines, however, poses its own difficulties. Generations of scholars have developed their knowledge within disciplinary contexts and their practices of study and knowledge exchange have worked well in communities of colleagues with similar conceptual frameworks (Pennington, 2008, p.8). In cross-disciplinary settings, in contrast, very few concepts are self-evident to all participants and the considerable confusion about concepts has presented the diversity of frameworks as a challenge as well as an asset (Dewulf et al., 2007).

Several authors have used the concept "knowledge integration" to denote the processes needed to develop shared understanding amongst researchers in cross-disciplinary collaboration (Jacobson et al., 2004; Newell et al., 2005; Akera, 2007; Dewulf et al., 2007). Newell and his colleagues (2005, p.299) present knowledge integration as "the blending of concepts from two or more disciplines to create innovative new worldviews." Pennington (2008, p. 8) refers to a "conceptual integration of perspectives." Yet the cognitive and conceptual connotations of this term deserve a caveat: Dewulf and his colleagues (2007) clarify that "exploring and connecting different ways of framing the issues is not just an intellectual task." They propose that the specific challenge is largely a matter of dealing with ambiguity and that "the way issues get framed has important relational implications." In other words: the task includes socio-emotional as well as intellectual aspects, which become more important to the extent scholars identify with their respective disciplines. All of these factors combined lead to the conclusion that knowledge integration is an important, yet far from straightforward process (Newell et al. 2005; Dewulf et al. 2007; Pohl et al., 2008). A second caveat to the notion of knowledge integration is that the very idea of 'integration' in cross-disciplinary settings – and even more so in the communication between scientific and informal knowledge communities – may lead to further marginalization of the non-dominant knowledge systems (Cundill et al., 2005).

5.2 Group Model Building: the model and the modeling process

One of the recognized approaches to knowledge integration is Group Model Building (Andersen & Richardson, 1997; Dewulf et al., 2007; Schwaniger et al., 2008), in essence a participative method to construct a joint framework of a phenomenon under study. Group Model Building tends to be

associated with a dynamic systems perspective, originally in the context of developing simulations in face-to-face meetings with clients. The methodology expanded to include decision-making in a variety of contexts – especially so-called "messy problems" (Vennix, 1999) – and web-based applications complemented traditional group work.

Andersen and his colleagues (2006, p.4) point out that, "while many GMB projects can and do end short of the construction of a fully calibrated and running simulation model, the construction of such finished models is the stated aim of classical GMB." They continue to distinguish between the model "as the end product" and "the process of working with the clients to construct that model."

In the course of this process, group model building and group building are interwoven (Richardson & Andersen, 1995; Zagonel, 2002), hence the benefits of a process facilitator, who encourages active participation and social learning by the stakeholders while refraining from 'product' interventions (Vennix, 1999, p.389; Werner, 2005,p.357)

The distinction between the group model as a product and group model building as a process includes the possibility that GMB contributes to joint understanding even in occasions where it does not result in a finished model.

5.3 Knowledge integration in NeWater

5.3.1.1 Group Model Building in the NeWater project

As the Newater project and its cross-disciplinary nature have been sufficiently explained earlier in this report, we will immediately focus on the Group Model Building process in this project. The Newater coordination team decided on a participatory approach to develop a common conceptual framework[1]. The NeWater Report # 12 captures its purpose as follows:

> The development of a joint product supports the process of integration and forces the group to make some decisions instead of being lost in endless discussions. Assumptions made during development (e.g. on what determines adaptive capacity or the relationship between vulnerability and adaptive capacity) will be documented during the framework production process (Pahl-Wostl, 2006, p.64).

In April 2005, early in the project, the WP17 group accepts the task to propose an initial "conceptual framework for regimes and transition dynamics" and a "qualitative influence diagram for the conceptual framework"[2]. In January 2006, they gather in the NeWater Framework Development Workshop with the objective to:

> Introduce an operational and integrated framework approach to implement system analysis and knowledge representation and communication, in support of the process of knowledge production and integration within NeWater and, in particular, for the achievement of (several) NeWater products. [3]

[1] Objective 1 of Work Block 1 reads: "To develop and apply a conceptual framework for research and adaptive management of River basins that integrates natural science, engineering and social sciene concepts and methodologies and that bridges the science-policy interface by actively engaging stakeholders in the research process" (NeWater, 2003. Annex I, Description of work, p. 23).

[2] The WB1 Meeting Summary of April 18th, 2005 stipulates under the title "Summary of next steps": "Conceptual framework for regimes and transition dynamics – refinement to make it more complete (lead CPW) – attempt to develop a qualitative influence diagram for the conceptual framework"

[3] Objectives of the meeting according to the *Summary Report of the NeWater Framework Development Workshop* organized by WP 1.7, 26th and 27th of January, 2006, p.1.

During that meeting, the project "adopted Unified Modeling Language (UML) as the modeling notation for the NeWater framework on transition towards Adaptive Management"[4]. UML is further introduced as a binding yet flexible graphical notation (Dewulf et al., 2007).

5.3.1.2 Unified Modeling Language

Unified Modeling Language (UML) is a codified, graphical language with origins in software engineering, where it is used for writing system blueprints. It relies heavily on graphical representations, which are combined with narratives that document the line of logic.

UML is presented in NeWater as "a standard notation for the modeling of real-world objects as a first step in developing an object-oriented design methodology"[5]. Among the reasons to use UML to support NeWater's GMB are the expectation that it will "force (those involved) to be precise"[6] about the meaning of the concepts they use and that it will facilitate communication across disciplines without imposing a certain perspective. The initiative-takers clarify that:

> Please note: UML is not a running model itself. It is rather a notification that allows documenting or specifying knowledge about objects, relations and associations, workflows and processes, responsibilities, information flows, interfaces, etc. UML supports different views on the same part of the world. All 'views' or diagrams share the same terminology and their level of detail depends on the degree of information that is required to understand a certain problem. Due to this approach a diagram is a view into a model presented from a particular perspective (e.g. a stakeholder), it provides a partial representation of the system, and it is semantically consistent with other views.

A intermediate evaluation based on participant experience and researcher observations (Dewulf et al., 2007) indicates that the use of UML in group discussions (1) helps make mutual assumptions explicit, (2) helps identify where knowledge of a system or process is incomplete. It suggests that UML does not rely on the often implicit and possibly diverging meanings of the visual aspects of the diagram, yet recognizes that people may still read those meanings into the visual aspects of the diagram and make diverging conclusions. The authors interpret the role of UML in the knowledge integration process in terms of Wenger's (1998) participation and reification concepts:

> Participation, meaning here involvement in the development of knowledge, needs reification, e.g., diagrams (or papers or reports) to store and "transport" this knowledge. But reifications always need participation: people need to be willing to learn and to use the new language and to work with it, otherwise the diagrams remain meaningless (Dewulf et al., 2007).

5.3.2 The Management and Transition Framework

Using UML in interactive sessions, face-to-face as well as online meetings, representatives of the NeWater consortium developed a conceptual model which they labeled the Management and Transition Framework (MTF). The first completed version of this framework was presented in a paper by Pahl-Wostl and colleagues (2008), who describe MTF as:

> An interdisciplinary conceptual framework supporting the analysis of water systems and management regimes to improve the scientific understanding of system properties and to give practical guidance for the implementation of transition processes towards more adaptive systems. The framework integrates a range of concepts to develop a more coherent understanding of the complexity of water management regimes. Specific emphasis is given to adaptive capacity and learning processes (Pahl-Wost et al., 2008, p. 75).

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[4] Pahl-Wostl, C. (Ed)(2007). *Integrated management and transition framework. Task 1.7.1 and 1.1.4*. USF, DRIFT, FEEM, p.28.

[5] Idem, p.28.

[6] Möltgen; J. & Rinke, K. 2006. *NeWater UML Tutorial for the development of the NeWater Framework*. NeWater internal document: http://www.newater.info/downloadattachment/2100/1275/UML_Tutorial.pdf

The MTF is a combination of graphical representations and narratives, composed of two core components, i.e. a 'static' and a 'dynamic' overview. The static overview represents entities in the world of river basin management, e.g. specific 'actors', 'institutions', 'rules', 'roles', 'mental models' etc. These are represented in Class Diagrams. The dynamic overview is represented in so-called (singel, double and triple) Loop Diagrams, which integrate elements of a formalized conventional management process, change based on a learning cycle and transition management.

5.4 Research method

As part of NeWater Task 1.1.5 and following our interest in the dynamics of cross-disciplinary research, we studied the Group Model Building process outlined above. Beside participant observation, interviews and participant evaluations, as reported under 4.3, we recorded the 2-day Framework Development Workshop – referred to as the Steinfurt meeting – for Interaction Analysis. Interaction Analysis goes back to the work of Bales (1950) and has since developed a variety of methods and approaches to investigate the interaction between humans through verbal and non-verbal communication, including the use of artifacts and technologies (Jordan & Henderson, 1995). The development of video-technology has played a major role in this development, but is not indispensable.

In our own study, the data consisted of 8 hours of video tape complemented with 6 hours of audio tape. As these data were gathered in a 'real-life' meeting rather than in a lab set up for video recording, the images did not allow an analysis of the role of artifacts – or only partially so – yet largely sufficed for a detailed analysis of verbal and para-verbal communication. The first author, who was at that time new to the NeWater project, selectively transcribed the recordings with a focus on significant or "barometric events" (Bennis & Sheppard, 1978, p.34) and further analyzed the interaction in terms of (1) Losada and Heaphy's bipolar dimensions related to group performance (2004), (2) themes in developing working relationships (Hovelynck, 2000) and (3) an open coding of issues related to UML and GMB. The results of these analyses were submitted to the co-authors, participant observers in the WB1 work stream during the entire NeWater project, for validation.

In addition, we analyzed the WB1 documents[7] available on the NeWater intranet to expand the timeframe of our inquiry and corroborate our Interaction Analysis with information on the circumstances and assumptions underlying interventions during the so-called Steinfurt meeting.

This paper presents the analysis of issues related to UML and GMB as an approach to knowledge integration. Open coding resulted in identifying 10 dilemma's in the process of knowledge integration, which could in turn be summarized in 3 overarching issues: 'simplicity versus complexity', 'constraining versus containing' and 'defining versus refining'. These 3 issues – dilemma's or paradoxes? – seem loosely coupled to Wenger's notions of reification and participation (1998), introduced earlier by Dewulf and his colleagues (2007).

5.5 Dilemmas in the process of knowledge integration

Open coding of the interaction at the 2-day Framework Development Workshop in Steinfurt resulted in identifying 10 clusters, which can be understood as issues related to UML and the GMB, with regard to which the WB1 participants ask questions and/or take position. Nine of these 10 issues are presented as dilemma's, i.e. bipolar choice-situations; for the 10th cluster, this is less clear. By taking position vis-à-vis these 10 issues, the participants in the meeting also position themselves in the discussion and vis-à-vis each other. In this regard, the clusters also represent sources of tension that needs to be managed to render a constructive GMB possible.

While our analysis proposes that the 10 clusters represent distinct issues, they also appear to be closely interwoven. Hence the clusters indicate a complex set of interrelated meanings relevant for knowledge integration, which we grouped in 3 overarching categories, i.e. 'simplicity versus complexity',

[7] References to these documents are presented in footnotes, unlike literature references.

'constraining versus containing' and 'defining versus refining'. We will discuss our findings under these three titles.

5.5.1 Simplicity versus complexity

A first cluster of data relates to issues about simplicity versus complexity. The researchers in the Framework Development Workshop have different expectations with regard to UML's capacity to capture the complexities of river basin management and with regard to the impact of its codified notation on the GMB. Some anticipate that the use of UML will result in an overly simplified framework while others view it as a tool to communicate this complexity less ambiguously. Simplicity and complexity appear to be associated with:

- Superficial versus rich understanding,
- Overview versus detail,
- General versus local knowledge,
- Abstract versus specific concepts.

Table 1 documents each of these dimensions with (condensed) excerpts from the data.

Table 1

SIMPLICITY	COMPLEXITY
SUPERFICIAL	RICH
▪ "..working a simple example, which unfortunately was far too simple for everyone. As if we were being pulled into a superficial description of the system, which wasn't allowing us to get into the richness of it." ▪ "Just using arrows and boxes."	▪ "We have to face complex systems that we don't understand"
OVERVIEW	DETAIL
▪ "We need a solid and well-thought through conceptualization of the whole system" ▪ "That is why we try to stay at a higher level." ▪ "From overall concept to more specific … We work top-down."	▪ "If we go into that level of detail, it would keep us away from concentrating on the project."
GENERAL	LOCAL
▪ "You try to comprehensively describe a system that is so big, that if there is no conceptual orientation on where to go, you end up with an informational overkill, huge heaps on what's happening in a basin…"	▪ "But working with narrative, you run exactly the same risk. You know, you might end up with 200 or 300 pages…" ▪ "Some knowledge management, some guidance about ... to find some things that are .. unique." ▪ "Linking the tools to the cases … Lift it up from a specific case again to…" ▪ "Work on the cases. We never have a generic river basin."
ABSTRACT	SPECIFIC
▪ "I want to get out of this workshop an understanding of what AWM is: who is involved, … what should be considered, at least at an abstract level and then to a certain level of detail." ▪ "From overall concept to more specific"	▪ "allow specificities and integration"

The position of the project management, represented in the WP17 group whose task it was to present an approach for developing a joint conceptual framework, is that UML allows sufficient complexity

while its coded graphical notation simultaneously pushes towards unambiguous communication across disciplines and cases (i.e. specific river basins as case studies). This finding is corroborated by position they took in later writings, stating that "The complexity of UML allows the representation of all real-world situations as dynamic elements" (Pahl-Wostl et al., 2008, p.82). From a "project management" perspective, they "judge UML extremely useful" because it allows that "complex system structures can be communicated unambiguously." The WP17 group in Steinfurt, however, appears to mostly hear an emphasis on unequivocal communication and ponder to what extent this will jeopardize the richness of local detail.

5.5.2 Constraining versus containing

Closely related to the distinction between simplicity and complexity is the dilemma between constraining and containing. The initiative-takers present UML as a means to link the disciplinary knowledge of participants with different educational and professional backgrounds: it is a structure that integrates different theories, and in that sense a 'container', holding a space for exchange and joint framework development. Several participants, however, anticipate that the UML format is incompatible with the theory they wish to contribute, hence becomes a constraint.

Containing versus constraining appears to be associated with:

- Types of knowledge,
- Open versus closed,
- Form versus content
- Structure versus theory.

Table 2 documents these four issues with excerpts from the data.

Table 2

CONTAINING	CONSTRAINING
TYPES OF KNOWLEDGE	
▪ "A representation that can hold the complexity" ▪ "I don't think it constraints, it is a way to document it." ▪ "How can you ensure that you're being systematic and rigorous? I see it as a way to ensure this."	▪ "It will constraint types of knowledge integration…" ▪ "Social sciences are less comfortable with such a flow diagram. … ▪ "Causal links .. do not help to understand a human-natural system nor does it help to understand transition" ▪ "In the scheme such as the one you designed, I can see how a box says 'this is something that I know something about'. But I don't see yet how I can put my kind of knowledge in such a scheme." ▪ "This shows us graphically but some people don't work graphically, but with words…"
OPEN	CLOSED
▪ "The framework … should be open. We can't impose entirely some research question." ▪ "I don't talk about the process, I talk about 'processes' … We try to get open."	▪ "There was some serious exchange on whether it was feasible to squeeze things in there or not."
FORM	CONTENT
▪ "I agree we need a visual representation and, yes, this is 'a' visual representation, but (…)" ▪ "Just using arrows and boxes."	▪ "I can't see how you can say it is neutral." ▪ "The thinking of the person who designed the boxes."

CONTAINING	CONSTRAINING
STRUCTURE	THEORY
▪ "What we need to agree on is some structure: we have so much knowledge together that we need to be specific…" ▪ "I don't think the diagram is like a blueprint for a model." ▪ "A template with questions." ▪ "At least we address similar topics. We don't impose a theory or something like that."	▪ "Of course there are quite a number of assumptions already on what transition is" ▪ "We should be careful: a framework implies some kind of knowledge, … some assumptions about what…" ▪ "We should start with the representation of a regime, generally somewhat applicable – quite accepted theory."

The position of the initiative-takers in this regards is clarified by Pahl-Wostl (2006, p. 63): "Please note: UML is not a running model itself. It is rather a notification that allows documenting or specifying knowledge about objects, relations and associations." A later paper takes a more distant point of view, recognize the issue and also linking it to the 'simplicity versus complexity' dilemma. Interestingly, the authors attribute the 'constrained' position to the methodical choice to use a simplified version of UML rather than to the structure and format itself:

> On the other hand, participants seem to feel constrained while trying to integrate their own knowledge and concepts. In fact, those constraints are due to the limitation to develop only class- and activity diagrams and can be eliminated by the introduction of further UML diagram types, e.g. collaboration diagrams. However, this would increase complexity and require a profound UML expertise (Pahl-Wost et al., 2008, p.82).

While the 'simplicity versus complexity' issue can be understood as primarily related to the nature of the study domain, the 'containing versus constraining' issue seems closely linked to group dynamics and the role of the GMB facilitator. In psycho-dynamic theory, 'containment' is viewed as a major function of the group leader. It involves "creating boundaries around the group that enable it to conduct its business with a reasonable sense of security and without interference or harm" (Ringer, 1995, p.191). In the context of the Framework Development Workshop under study, the interaction analysis indicates that such "sense of security" is related at least partially to issues of inclusion versus exclusion (Srivastva et al., 1977: Hovelynck, 2000, p.165, 423), characteristic for early group development. More concretely: at least some participants doubt that their "kind of knowledge" can be included in the overarching framework if UML is the required format; the data suggest that "people who don't work graphically" and "social sciences are less comfortable with this… "

5.5.3 Defining versus Refining

A third cluster of data relates to issues about defining versus refining. Some of the researchers in the Steinfurt meeting sense that UML is proposed as the (format for a) definitive NeWater framework whereas others view it as a mere starting point for clarifying concepts and developing a joint vocabulary. Defining versus refining appear to be associated with:

- Perfectionism versus Pragmatism
- (Re)presenting versus Learning

Table 2 again documents these dilemma's with a few excerpts from the data.

Table 3

DEFINING	REFINING
PERFECTIONISM	PRAGMATISM
▪ "It shouldn't be thought of as perfect, should be thought of as some (buoy) that we will work on for years."	▪ "Just a start, we will redesign it more and more next year." ▪ "A pragmatic approach" … "Let's continue and see how these things work out in practice." ▪ "Attempt to refine … still pretty messy … more coherent … just one further step"
(RE)PRESENTING	LEARNING
▪ "One thing that got in our way is that … we were going to present this to the world, almost, hence it must be a perfect representation that anybody can use. …"	▪ "This tool really ought to be more about jumping in the water together, getting into difficult questions together."

While our analysis clearly indicates that the project management in the Steinfurt meeting intended UML as a basis for further, joint development of an integrative framework, the WP17 group did – initially – experience it as a more definitive format, or even a rather definitive (within the NeWater timeframe) representation of river basin management regimes. This shifts when one of the participants recognizes the tension and articulates the underlying assumption that UML is about 'definitive representations'. Newell and his colleagues – including researchers present at the Steinfurt meeting – refer to the tension between defining and refining in the following terms:

> It is important to recognize that the process of constructing and refining a conceptual template is intended to help a research team to initiate and sustain richly connected discussions, without imposing too rigid a point-of-view (Newell et al., 2005, p.303).

While the dilemma of constraining versus containing links our data to group work and facilitation, this third issue appears to link it to notions of experiential and social learning – learning being a process of 'refining' rather 'defining' (Hovelynck, 2000).

5.6 Conclusions

By means of summary, our analysis of the interaction in a 2-day Group Model Building workshop identified 10 distinct yet interrelated dilemma's in the knowledge integration process. Further analysis suggests that these can be understood in terms of three overarching dilemma's, with regard to which the workshop participants take position and, in doing so, position themselves vis-à-vis each other. We labeled these three dilemma's 'simplicity versus complexity', 'containing versus constraining' and 'defining versus refining'. These three dilemma's respectively group dilemma's with regard to:

Simplicity versus complexity:
- Superficial versus rich
- Overview versus detail
- General versus local
- Abstract versus specific

Containing versus constraining:
- Types of knowledge
- Open versus closed
- Form versus content
- Structure versus theory

Defining versus refining:
- Perfectionism versus pragmatism
- (Re)presenting versus learning

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6 CONCLUSIONS AND RECOMMENDATIONS

In this final chapter we bring together the practically relevant results discussed in the previous chapters, in the form of recommendations for fostering knowledge integration in cross-disciplinary research collaboration. We will use a number of issues and challenges discussed by Hadorn et al. (2008) to start and structure this chapter.

6.1 Challenges for cross-disciplinary research

Cross-disciplinary research has arisen from a growing number of complex problems in the life-world for which knowledge of a single scientific discipline or societal field is insufficient. In order to be effective, cross-disciplinary research needs to face scientific, institutional and societal challenges (Hadorn et al., 2008). Traditional scientific practices are not conducive to cross-disciplinary research. Important features of the scientific reward and recognition system (e.g. publications, job opportunities, …) are evaluated mainly in a disciplinary way. Involvement with practical societal problems is valued only insofar it leads to more or better publications. Researchers engaging in cross-disciplinary research thus need to invest in disciplinary and cross-disciplinary activities simultaneously. The institutional challenge consists of the peripheral position of cross-disciplinary research in academia. It is often associated with applied research institutes or packaged in temporarily limited projects or programmes. Finally, the societal challenge lies in the science-society interface. The role and image of science in society, and the conception of the society in science have important consequences for cross-disciplinary research that takes complex societal problems as a starting point. Uncertainties, multiple frames, values and both scientific and societal stakes have to be dealt with.

Hereafter we will address some of the major issues in cross-disciplinary research discussed by Hadorn et al. (2008). We selected those issues that are most relevant to the NeWater project and where we can add to the discussion based on our observations and analyses of this particular project. The main focus is on issues related to knowledge integration in cross-disciplinary research collaboration.

1. Integration and collaboration.

Collaboration to integrate the perspectives and knowledge of various disciplines is a core feature of cross-disciplinary research. This challenge starts at the very beginning, where the process of problem definition and framing starts, which is usually well before a project starts. The issues is not only a communication problem and integration cannot wait until the end of the project. Integration efforts should avoid to privilege one discipline over the others and leave enough room for participating disciplines and researchers to manoeuvre. Hadorn et al. (2008) suggest combining different means of integration: theoretical concepts, models and practical outputs.

In the NeWater project all these means of integration were used. The process of building a joint theoretical framework for understanding adaptive water management and transition processes was initiated from the start of the project. The development of a qualitative conceptual model using unified modelling language (UML) through the process of group model building was adopted as a means to develop and capture the conceptual framework. Practical outputs were used as means of integration as well, e.g. developing or adapting tools, carrying out case study activities or developing synthetic guidance documents for stakeholders. One of the major difficulties in this integration process was the amount of time required to develop the theoretical framework. Multiple strands of activity within the project were dependent on this theoretical framework and therefore also suffered delays or went on with their activities without considering the theoretical framework. The challenges for integration posed by the different ways of framing research issues have been addressed in Chapter 4. Recommendations derived from this analysis will be discussed further down in this chapter.

2. Recursive process

In cross-disciplinary research, determining the problems involves making fundamental decisions about what aspects are seen as important and what questions will be addressed. A recursive process implies that problems can be restructured and assumptions revised over the course of the research. The precise

nature of the problem to be addressed should be not predetermined but framed and reframed cooperatively by scientific and societal actors, ideally including the sponsor as well.

Applying this to the NeWater project reveals that this process of refining is not an unproblematic one. Even apart from the intellectual willingness and adaptability needed to revise research questions, a number of constraints present themselves. The sequencing of activities presents also challenges here – delaying research activities until the central questions have been recursively refined is not an option. Often contact with stakeholders, methodological problems or pilot results are powerful triggers for changing questions. But as research activities start, they develop their path in which time and resources become invested, making changes difficult to manage. The requirement to predefine outputs of a cross-disciplinary research project is also problematic from this perspective. If even the central questions are subject to change over the course of the project, predefining the outputs can be counterproductive. The challenge of recursively refining concepts presents itself also at the interactional level, and was captured in Chapter 5 by the dilemma between "defining" and "refining" in group model building with UML.

3. Participation and mutual learning

According to Hadorn et al. (2008), participatory research processes in require carefully structured, sequenced and selected negotiations and interactions. The diversity of goals, values, expectations and related power constellations in both society and science need to be considered. Building on approaches of mutual learning that bridge roles and positions without dissolving them is a promising entry point to goal oriented participation.

In the NeWater project structuring and sequencing interactions between researchers and stakeholders was a major challenge. Given the matrix structure of the project where multiple thematic work blocks were connected to multiple case studies, matching research lines with case contexts involved a complex coordination process between a diverse group of researchers expecting something from the cases, and a diverse group of stakeholders expecting something from the researchers. The task of tuning these expectations turned out to be a demanding one for the case study leaders. In general, opportunities for learning between researchers and stakeholders have been mostly limited to the central researchers and stakeholders involved in a specific case. Opportunities for participation and mutual learning between researchers have been actively stimulated: as we documented in Chapter 4, a number of interventions were undertaken from a social learning approach to enhance mutual learning between researchers.

4. Management and leadership

Managing or leading cross-disciplinary research is an especially demanding challenge. According to Hadorn et al. (2008), it requires dealing with the production pressure resulting from the expectations of funding agencies while competing on the science market with disciplinary research. At the same time, sufficient time and resources need to be invested in mutual learning and a recursive research process.

In the NeWater project, this tension takes the form of trade-offs between investing in developing and investing in delivering. This issue is simulation to what is known in innovation studies as exploration (developing the necessary knowledge) versus exploitation (putting knowledge to practical use in tangible outputs). The difference is that in this case both exploration and exploitation are cross-disciplinary endeavours. Investing enough time and resources in both developing and delivering seems crucial, and Hadorn et al. (2008) suggest that both activities should be allocated to separate periods of time, iterating multiple times over the course of the project. Maintaining the same group composition over the periods of developing and delivering is important to assure the best possible use of the jointly developed knowledge and facilitates the management of internal and external recognition of intellectual property.

Leadership in this kind of multi-actor setting may focus either on the task at hand or on the process. When leaders focus exclusively on the task (gathering information, working out plans, managing budget, etc.) the results risk to be sub-optimal because they do not take into account all relevant information. In such cases a strong leader may provoke high dependence in some actors and/or resistance from actors who feel excluded or put at a disadvantage. In fact, strong process leadership

may be critical to create conditions to get the most out of the diversity of perspectives, competencies and resources, while ensuring that each stakeholder can meet his own objectives. Managing the inherent tensions in the relationships among actors in inter-dependent work is an important aspect of process leadership. This kind of leadership can be understood as convening the actors and keeping the collaboration going, rather than steering and controlling the process unilaterally.

6.2 Interventions for connecting multiple knowledge frames

As we reported above in our analysis of cross-disciplinary research collaboration from a framing approach (Chapter 4), a number of interventions were tried out in the project from a social learning approach, in order to foster constructive ways of connecting knowledge frames from different backgrounds. A number of recommendations can be formulated regarding these interventions.

1. To allow for open and mutual questioning in the exploration of different frames, interactive workshops, and especially highly *interactive work forms* like break-out groups, are useful, both on the content and the process level.

2. Seperating the complementary roles of presenting versus chairing or *facilitating* the meeting allows for more opportunities for open discussion across different frames. The roles of chairing and presenting can usually be taken up by meeting participants. Additional support for the process of learning and dialogue can be provided by involving a trained (internal or external) facilitator.

3. *Group model building* and translating disciplinary and cross-disciplinary insights into a common formal language helps to make mutual assumptions explicit and making the differences between participants' frames more visible and understandable. The subject of group model building will be discussed in more detail in the next section.

4. As a way to deal with diverse methods or theories, using *concrete or stylized case situations*, either presented by a participant or experienced by a common site visit, allows participants to use the case situations as a common ground to which the various frames could be connected.

As we have argued, cross-disciplinary research requires dealing with diverse frames, which often take the form of tacit understandings implicit in how disciplines or theories select, focus and embed aspects of the world, and how they formulate these issues in a specific vocabulary. If we try to reason a step further from these findings, we can suggest a hypothetical process of optimal steps in dealing with cross-disciplinary frame difference, after a preliminary focal issue has been put on the table.

1. *Getting to know each other's frames*. A first step is to be confronted with the different kinds of knowledge others contribute.

2. *Acknowledging differences*. This requires paying attention to differences and not to continue as if there were none.

3. *Incorporating other concepts into your own frames*. A first and perhaps inevitable step in understanding other frames is to translate them into your own terms. This does not do right to the full richness of the knowledge, but is probably necessary as first approximation (like translating words is often a necessary intermediary step when learning a foreign language).

4. *Exploring and working with the differences*. A step further is to mutually explore the different views so that each can understand the other view in its own terms, in order to sort out in more detail where frames are incompatible and where they provide complimentary contributions.

5. *Forging new frames*. As a way of integrating different frames, often a new vocabulary has to be created that is able to carry the new and jointly created meanings and knowledge.

These kinds of processes set high requirements in terms of interaction and learning between researchers.

6.3 Knowledge integration through group model building with UML

In Chapter 4 we concluded that using UML in group discussions helps to make mutual assumptions explicit, because everybody attempts to translate his or her concepts into a common language. In

selecting aspects, labelling them, drawing the relations and labelling the relations, differences between participants' frames can emerge and can be discussed. Creating the diagrams also helps to identify where knowledge of a system or process is incomplete.

Through a close analysis of group model building sessions (Chapter 5), three core dilemma's for knowledge integration through group model building were identified: 'simplicity versus complexity', 'constraining versus containing' and 'defining versus refining'. For each of the three dilemma's, it seems necessary to address both sides of the dilemma in knowledge integration processes despite the obvious tension between the sides.

The dilemma of simplicity versus complexity involves tensions between superficial versus rich understanding, overview versus detail, general versus local knowledge and abstract versus specific concepts. The whole endeavour of conceptual modelling could be understood as simplifying a complex system to manageable proportions. This means that, on the one hand, knowledge integration needs to be able to acknowledge and capture the rich, local, detailed and specific knowledge into the model that is being built. On the other hand, if the model becomes as complex as the phenomenon it aims to understand, the model looses its conceptual utility of providing a general and abstract overview. An important criterion for any model is the question whether it provides more or new insights into a complex phenomenon.

The dilemma of constraining versus containing involves tensions between open versus closed, form versus content and structure versus theory. Developing a group model with maximum possibilities for integrating diverse types of knowledge needs a process and a language that is sufficiently open, where the modelling language functions as a form able to capture and integrate diverse contents, and as a structure to capture and integrate diverse theories. On the other hand, starting from a white page is unfeasible and undesirable – some initial framing of the topic, system or phenomenon will inevitably be needed as a starting point any group model building, and in this sense some content or concept gets fixed. To the extent that this starting point constrains possibilities by privileging certain contents or theories, it prematurely closes the exploration process. What is needed are probably *minimal structures* as starting points. These minimal structures – a new concept, a minimal starting model – can work if they are recognized by participants as useful even if not neutral starting points. Working with multiple starting points – or in general, multiple alternative models – is another way to increase the chances that all relevant kinds of knowledge are included and connected.

Options for containment by a facilitator include the use of cases and a need for joint action. Also here, cases bring a concreteness to the inquiry that facilitates the recognition of others' – and other disciplines' – perspectives. A concrete task brings a criterion for assessing when cross-disciplinary perspective-taking suffices for aligned action. As we discussed above, *situated frame reflection* is needed for dealing with frame conflicts. Reflecting on the involved frames with the aim of getting to a pragmatic solution in a specific context is likely to be more successful than trying to integrate diverse (disciplinary) frames in the abstract. Therefore, the role of the case studies in projects like these are crucial in fostering cross-disciplinary outcomes.

The dilemma of defining versus refining involves tensions between perfect representation on the one hand, and pragmatic learning on the other hand. Although *defining* how something will be represented in the model is a continuous task in group model building, these definitions (and even resulting models) should be treated as provisional and open to further *refining*. Rather than a contest of definitions a reciprocal process of refining mutual understanding should lie at the core of a group model building process.

6.4 General recommendations for large cross-disciplinary projects

A first observation is that size matters. The complexity of a project increases exponentially with the number of project partners or disciplines involved. The pressure to bring together different research networks in the NeWater project led to a constellation of 35 institutes and over 100 researchers. The integrated character of the research made it very difficult to break the project down into separate sub-units, so collaboration and mutual learning was basically needed at the level of the entire project. The chances to put this in practice effectively and efficiently would be enhanced by reducing the size of such projects. With a very large project such as NeWater, lack of time and interaction possibilities

force participants (researchers and stakeholders) to look for reified information and knowledge through reports or portals, missing opportunities for in depth cross-disciplinary frame reflection.

The classic pattern of submitting proposals, competing on disciplinary criteria and preplanning the research in detail before the start of the project do not create ideal starting conditions for cross-disciplinary research. Especially if societal application is expected, the flexibility to accommodate to research questions and priorities as they present themselves in practical contexts should be enhanced by more flexible funding and planning arrangements.

We already mentioned the coordination difficulties between a variety of researchers and a variety of stakeholders when case studies are used. In the Newater project a 'market' was organized, an interesting idea in the circumstances that supply (research) and demand (stakeholders) are supposed to meet. Researchers try to satisfy their research needs trough the contacts with case coordinators who mediate for their stakeholders. On the research side, everybody wants to be served, but the degree to which particular research needs are relevant for stakeholders has to be watched over. On the case side the relationship between case coordinators and the stakeholders becomes crucial, but how much can you expect in the early phases of a project. So the commitments made at the initial market exercise are provisional at best and should be renegotiated among the broader group of researchers and stakeholders connected to a specific case. They have been renegotiated but generally in a smaller subset of researchers and stakeholder. A model that could improve the situation is foreseeing a preparatory proposal phase for about one year, where scientists and stakeholders can explore and match needs and interests. Starting from where the stakeholders are, research can then be brought to bear upon their needs, and a much more meaningful proposal can thus be developed.

Learning from past projects is another important issue to consider. It is generally not systematically addressed by funding agencies. At best it is taken up by individuals, and past learning is only partially represented in new proposals, while funding agencies have crucial information about ongoing and past projects (proposals, products, learning reports, evaluations, …). This pleads for systematic debriefing (lessons learned) and briefing for new projects as a role for funding agencies.

6.5 References

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