



Cross-disciplinary research collaboration : challenges and experiences from a large-scale research project on adaptive water management

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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.

Keywords : Adaptive management, Cross-disciplinary research, Framing.

1. 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.

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.

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

2. The Farming 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.

3. 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 :

- How do researchers differ in framing a central concept?
- What challenges do framing differences pose for the project?
- How useful are the interventions undertaken from a social-learning approach for dealing with these differences in framing?

4. 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 interpre-

tations 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.

5. 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.

5.1 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.

5.2 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.

5.3 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.

5.4 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.

6. 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 methods or the planning of interventions in the case studies.

7. 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.

- *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.
- *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.
- *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.

8. 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.

9. 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.

10. 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.

11. 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.

12. 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.

13. 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.

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

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

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