Pre-requisites to interdisciplinary research for climate change: lessons from a participatory action research process in Île-de-France

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Abstract: The complexity of climate change issues translates itself into a need for interdisciplinary approaches to first achieve a more comprehensive vision of climate change, and second to better inform the decision-making processes. However, it seems that willingness alone is rarely enough to implement interdisciplinarity. A participatory action research process undertaken within the Scientific Consortium for Climate, Environment and Society (GIS CES), France, has allowed to take insights into the important features for launching, facilitating and developing interdisciplinarity, as perceived by scientists working on climate change and its social, economic and environmental impacts: a) getting to know each other in the personal dimensions; b) getting to know each other in the disciplinary dimensions; c) agree upon the definition of interdisciplinary science; d) define collaboratively the purposes and means for the interdisciplinary project. The purpose of this paper is to explore and discuss these four 'reflexive pre-requisites' in the context of the GIS CES, in order to start a reflection on the important features to achieve interdisciplinarity.

Keywords: interdisciplinary science; reflexivity; climate change; Scientific Consortium for Climate, Environment and Society; GIS CES.

Reference to this paper should be made as follows: Blanchard, A. and Vanderlinden, J-P. (2013) 'Pre-requisites to interdisciplinary research for climate change: lessons from a participatory action research process in Île-de-France', *Int. J. Sustainable Development*, Vol. 16, Nos. 1/2, pp.1–22.

Biographical notes: Anne Blanchard is a doctoral research student in social and human sciences. Her PhD thesis, jointly supervised by the REEDS Laboratory at the University of Versailles Saint-Quentin-en-Yvelines, and the Centre for the Studies of the Sciences and the Humanities at the University of Bergen, Norway, is funded both by REEDS and the Scientific Consortium for Climate, Environment and Society of the Ile-de-France Region. It addresses the challenges of implementing interdisciplinary science for climate change research, and explores the links between interdisciplinarity and interfacing climate sciences and society.

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1 Introduction

Researchers and practitioners who commit to interdisciplinarity know that its origins, definitions, objectives and mechanisms are surrounded by fuzziness and complexity. This context translates to a need for those involved in interdisciplinary projects to explore these complex features (Blanchard and Vanderlinden, 2010). Moreover, a participatory action research process undertaken in 2009 in the Ile-de-France Region (see Section 3), led within the Scientific Consortium for Climate, Environment and Society (GIS CES), and composed of a set of 15 semi-directed interviews of scientists working on different aspects of climate, showed the importance to reflect on four important features to the practice of interdisciplinary research on climate change:

a getting to know each other in the personal dimensions

b getting to know each other in the disciplinary dimensions

c agree upon the definition of interdisciplinary science

d define collaboratively the purposes and means for the interdisciplinary project.

There are thus two main objectives of this paper. On one hand, we will describe the participatory action research process between us (the action researchers and authors of the paper, STS scholars/environmental scientists with interdisciplinarity as our research interest) and a group of scientists (the GIS CES); interactions aiming at facilitating interdisciplinary dynamics. On the other hand, we will report the substantive outcome of this process, formulated in terms of 'reflexive pre-requisites', i.e., situational elements perceived by us and the GIS CES to be requisites for the launching, facilitation and development of improved interdisciplinary dynamics in the GIS CES context of research on climate change and its social and environmental impacts. Hence, the reflexive pre-requisites presented in this research are context-based; the paper does not aim to present pre-requisites that are generalisable to every interdisciplinary setting, but rather, it intends to start a reflection on the important features to achieve interdisciplinarity, by proposing an example based on the GIS CES scholarship.

From a historical point of view, the concept of pre-requisites for interdisciplinary research has been explored in the literature at different levels. Davis (1988) focuses on linguistic pre-requisites and proposes that

1 group members need to agree to approach the topic according to an interdisciplinary perspective

2 group members need to formulate the global question together

3 a translation of the global question into the disciplinary languages is needed

4 group members must agree upon an answer which must integrate all particular answers available.

These linguistic pre-requisites are underlined by Hunt (1994), who considers that conversation across the disciplinary boundaries requires willingness to learn each other's language, each other's techniques of analysis and the nature of the other's results in that field. Brewer (1999) rather emphasises the logistical pre-requisites like strong and varied network facilities among group members and places to communicate. Jakobsen et al. (2004) underline personal pre-requisites such as respect, talented leadership, risk taking, or kindness. In the context of environmental research, Brewer (1999) highlights institutional pre-requisites as well, by affirming that the various sciences and policies need to be reconciled in the face of the growing importance of environmental problems. According to him, specialised views, theories, and tools have to be integrated to achieve a larger understanding and to improve performance.

This paper aims to complete the above pre-conditions by proposing and discussing another kind of pre-requisites, the reflexive pre-requisites. The concept of reflexivity, as the grounding idea of these pre-requisites, has found active expression over the past half century, and has been approached from several perspectives. Beck (1992) and Giddens (1990) associated the idea of reflexivity with a learning process, through the notion of modernity. Accordingly, modernity produces and develops adverse effects, or risks, to which society has to adapt. The process according to which society is becoming more aware, reflective, and hence reflexive regarding the problems of risk production was dubbed 'reflexive modernity'.

A second approach to reflexivity was proposed in the 1950s by Merton (1948, 1973) through this discussion of the 'self-fulfilling prophecy'. Merton argued that once a prophecy or theory is introduced, actors may modify their behaviours and actions so that a statement that may otherwise have been false becomes true, and vice versa. Hence, a prophecy or theory is not only describing the world, but is part of it, and influences it. This may question the credibility and validity of science; if a theory can change the world into which it is introduced, and then it becomes difficult to evaluate scientific hypotheses by comparing their predictions with the events that occur in reality.

A third, more methodological approach to reflexivity emerged in the 1970s with Bloor's (1976) 'strong programme'. For these authors, reflexivity is demanded because researchers' observations of, and actions within, society influence the system within which they are leading inquiries. Hence, reflexivity is suggested as a methodological principle to deconstruct science, and keep track of its social, political, historical and cultural influences.

Finally, building on Bloor's 'strong programme', Bourdieu (1988, 1996, 2001, 2003) claimed that researchers bear intrinsic biases. He argued that scientists can only

understand the implications of their biases on their research, by reflexively questioning the origins of these influences. Hence, reflexivity is as an act of self-examination to achieve a deeper understanding of one's own functioning, values, motivations, and to better appreciate one's relationship with the world. Reflexivity is a behaviour that takes the shape of a reflection-action spiral, where reflection influences the actions on the world, and in return, the world affects the reflection.

In our paper, we talk about reflexivity in Bourdieu's sense, i.e., the capacity of a researcher to recognise his or her personal and environmental influences, and adapt his or her relationship to other researchers or other disciplines.

To highlight the contributions of reflexivity for interdisciplinary research on climate change, the paper is organised around three parts. The second section aims to make our theoretical assumptions on interdisciplinarity explicit, as they steered to some extent our research task. The third section describes the participatory action research process between the GIS CES scientists and us. Finally, the fourth section exposes the outcomes of this process in terms of reflexive pre-requisites perceived both by the GIS CES scientists and us.

2 Theoretical elements on interdisciplinarity

Before having a deeper look at the participatory action research process that revealed pre-requisites to interdisciplinarity within the GIS CES context, this section aims to clarify our theoretical assumptions on interdisciplinarity, that guided us during the process of inquiry. Indeed, as our research attitudes and choices (i.e., our interview questions) were oriented by these theoretical assumptions, it is necessary to make them explicit in order to facilitate the distinction of our influences on the claims of the GIS CES scientists that helped building the reflexive pre-requisites.

Interdisciplinarity is a complex concept, holding multiple meanings depending on whether the reference is to programmes, courses, research areas, modes of teaching and learning, or administrative structures. Klein (2000) states: 'Ask three scientists what interdisciplinarity means, and they will likely give three answers'.

To avoid what the author calls the 'jungle of phenomena', Klein and other authors propose to define interdisciplinarity relatively to disciplines and institutions. Klein (1990) defines disciplines as 'deeply fissured sites' which experience 'the push of flourishing fields and the pull of strong new concepts'. They are thus dynamic systems that evolve and adapt to changing environments, ideas and influences, by producing reformulations of their knowledge. Bauer (1990) acknowledges this instability, but finds a common trait to disciplines, by comparing them to different language groups: 'Just as languages are distinguished more by grammar and syntax than by vocabulary, so disciplines are distinguished more by theoretical and methodological points of view than by the facts they contain'. Ferris (2003) supports Bauer's claim by saying that disciplines differ not simply through being knowledge about different subjects, nor because they use different methods for getting knowledge. Disciplines differ in what is viewed as knowledge, and in opinion over what is interesting and what is valuable. Practitioners and researchers have thus different habits and practice; and, more deeply, various attitudes toward truth. This entails different opinions over how to choose research projects, and how to create and validate knowledge. By seeing disciplines as cultures, disciplinary knowledge – its methods and approaches, cannot be isolated either from the history and practice of the

field or from its practitioner (Kuhn, 1970). Sill (2001) illustrates Kuhn's assertion by analogising disciplines to 'matrices of thought, each supported by assumptions that are themselves frequently invisible and unquestioned'. Fuller (1993) goes further by claiming that disciplines are even more complex entities, composed not only of a single matrix but of multiple matrices. Some of the matrices involve cognitive functions including disciplinary methodologies and a body of knowledge, while other matrices involve social interactions and professional connections. As a result, when two disciplines come together to collaborate around a common topic, interdisciplinarity leads to the crossing of families of matrices, some cognitive and some social.

While approaching interdisciplinarity through disciplines gives us a sense of what happens, it does not yet give us an understanding of how it happens: 'we somehow work with a black-box, knowing something about the input and something about the outcome, whereas we do not know what is happening between them' (Sill, 2001). This is why we use a second theoretical perspective on interdisciplinarity to draw its definition.

The second perspective, mainly based on Sill (2001) and Mourad's (1997) work, and on the idea that interdisciplinary dynamics cannot be reduced to a 'transgression' nor an 'integration', approaches interdisciplinarity through the concept of 'research programmes' and 'guide-supply relationship'. It completes the first perspective on interdisciplinarity by providing deeper insights into what happens when two disciplinary entities, formed by cognitive and social matrices of thought, come together. The first component of this perspective are research programmes. According to Sill, scientific practice is more adequately described by research programmes than by the historical and institutional settings of disciplines. The concept of research programmes was introduced by Lakatos (1970), describing the actual topics and aims scientists in a particular discipline work on. Over time, two or more disciplinary research programmes might affiliate. By doing so, their aim is to take ideas out of their disciplines, to allow them to be pursued without being constrained by disciplinary assumptions. Researchers seek to create a dynamic between disciplines that produces a new concept. Modern disciplines function hence as points of departure for new paths of thought rather than as top-down structures that largely determine the nature and course of particular inquiries.

The second component of this perspective on interdisciplinarity – the 'guide-supply relation' – gives insights into how the crossing of at least two research programmes can be managed, in order to achieve interdisciplinarity. Zandvoort (1995) asserts that in order to implement an interdisciplinary approach, the relationship between the participating research programmes should be non-hierarchical, and based on a 'guide and supply mode'. In the 'guide mode', a research programme formulates a task or a hypothesis, which is adopted and dealt with by another research programme, claimed to be in the 'supply mode': 'Some of the research programmes do not define their own primary problems. Instead, they aim at solving problems arising in and defined by other research programmes. The latter programmes may not themselves have the effective means to solve those problems'. Often, the participating research programmes switch from one mode to the other during the research practice, according to their respective needs and expectations. For this cooperative relationship to occur, scientists have to jointly draw a formulation of the problem, the research and the results, that is sufficiently precise and operational, in order to satisfy both the guiding and the supplying research programmes.

These two perspectives, brought together, form a framework that provides detailed insights into

1 what occurs at the boundaries of disciplines

2 how this occurs, and emphasises the need for reflexivity.

The definition of interdisciplinarity can hence be expressed as follow:

> "Interdisciplinarity is a meeting of families of cognitive and social matrices, or research programmes, in a non-hierarchical basis, where researchers share tools, methods, approaches and values, to the understanding of a common topic."

This implies that they have to be aware of and reflect on the boundaries, rules and values of their own discipline, and recognise the influence of their home discipline on the relation to others. In this regard, while disciplines keep their identities during the interdisciplinary collaboration, and have defined and discrete roles, it is a shortcut to consider interdisciplinarity as an integration or transgression process. Hunt (1994) illustrates this point by defining interdisciplinarity as a negotiation, in which disciplines must "learn to understand each other and give up some territory in the interest of long-term balance, without giving up their individual identities".

To sum up, the literature on which our assumptions on interdisciplinarity are based appears to emphasise the contributions of reflexivity for its successful implementation. Indeed, unexplained and unquestioned norms, values, and ways to see the world might lead to misunderstandings among various disciplines of a same project, regarding the setting up of objectives and means.

3 Case study description and method

3.1 Setting the goals of the participatory action research process

With our theoretical assumptions made explicit in the previous section, we will now present the interactions between us and a group of scientists, held over the period March–April 2009, which this paper will discuss. The interactions were undertaken within the framework of the Parisian Scientific Consortium for Climate, Environment and Society (GIS CES), set-up in 2007 by six members, including research institutions, universities and the Ministries for Environment and Education. It is composed of 13 research centres working on climatology, hydrology, ecology, health, social sciences and humanities. The mission statement of the GIS CES includes the fostering of interdisciplinary dynamics within these laboratories around cross-disciplinary research projects on climate change. The projects that this consortium fund generally last three years, and are following four main interdisciplinary directions: climate change and health; climate change and vulnerable regions; climate change, ecosystems and use of soils and water resources; and climate change and policies.

In March 2008, the GIS CES steering committee and scientists decided to fund the participatory project RAMONS (Research and Animation: Mobilisation and Structure of Interdisciplinary Knowledge, and Interface between Science and Society) to provide guidance to GIS CES scientists on the implementation of interdisciplinarity in effective and long-lasting ways. To this end, our interactions with the GIS CES scientists through the RAMONS project followed a participatory action research approach, the direction of which was steered by a number of our theoretical assumptions. In brief, participatory action research is an iterative research process, in which practitioners and researchers

collaboratively define the problem and choose the actions to take, assess and discuss the consequences of their actions, and eventually modify their theory and refine the actions to make them fit better to their ethical objectives and ambitions (Brydon-Miller et al., 2003; Checkland and Holwell, 1998; Greenwood and Levin, 1998; Kemmis, 2001; Reason and Bradbury, 2006; Stringer, 2007a, 2007b).

Specific to the results presented within this paper, the iterative and participatory action research implemented through RAMONS followed two goals:

1 verifying and measuring the contributions of reflexivity to interdisciplinary research

2 mapping the current interdisciplinary practices within the GIS CES, in order to communicate their nature to the scientists.

The process was composed of four stages, at the end of which we and the GIS CES scientists formalised four reflexive pre-requisites to interdisciplinarity. As our mindset and framework of ideas developed with the inquiry, the iterative process allowed us to verify at each step the accuracy and relevance of our analysis with the GIS CES scientists; constantly discussing and adjusting our results in light of our changing perceptions.

3.2 Building the semi-directed interview questions and selecting the participants

The first stage of the participatory action research process was an exploration of the current practices of interdisciplinarity within the GIS CES, in order to share with the scientists information on its overall current form. To do so, our mapping of the GIS CES interdisciplinary practices began by reviewing the literature of interdisciplinarity. Two literature reviews, accessible on the GIS CES website (http://www.gisclimat.fr/projet/ramons) were produced; their main theoretical underpinnings have been presented in Section 2. The literature highlighted the context-based nature of interdisciplinarity, thus emphasising the variety of purposes and methods for its implementation. It also reported on the benefits of reflexivity for the achievement of such dynamics. With these theoretical elements as a point of departure, we built interview questions to highlight the representations, experiences and motivations leading to interdisciplinarity, as well as the barriers and facilitators met by the various GIS CES projects. This was encompassed within the broader objective of evaluating the contributions of reflexive practice for interdisciplinary research.

We chose to ask our questions within a semi-directed interview framework to allow scientists to express themselves in a spontaneous way, and hence structure their experiences, observations and ideas according to their own scale of importance. We tested our set of semi-directed questions with two GIS CES project leaders, in order to check their comprehensibility, coherence, pertinence and completeness, as well as the interview time. This testing drew attention to the need for a question on the definition of interdisciplinarity, and its differences between pluri, multi, and transdisciplinarity. This question, added afterwards, highlighted contradictions among GIS CES scientists, as well as numerous confusions. Furthermore, we added the notion of ‘surprise’ to our last question, in order to embrace a broader range of experiences. The final version of the interview framework was organised around four questions (see Table 1), meant to last approximately one hour.

Table 1 Questions to the project leaders

Question 1	How would you define pluridisciplinarity, multidisciplinarity, interdisciplinarity, and transdisciplinarity?
Question 2	Through your previous research experiences, what are the elements that legitimate for you today the commitment to interdisciplinarity?
Question 3	What are the purposes of your interdisciplinary project? In practice, what methods do you use to implement your project?
Question 4	Regarding the interdisciplinary project that you are currently leading, what observations could you do in terms of successes, barriers, and surprises?

Of the 30 GIS CES scientists approached, 15 chose to participate in our semi-directed interviews, with subsequent saturation in data analysis indicating that this was sufficient participation for the research. In order to maximise the diversity of experiences, interviewees were selected from across a diversity of disciplines (see Table 2), and included both project leaders and members of the GIS CES steering committee, as representative of both the level of the 'funder' and the 'funded.' The role of the project leaders is situated at the practical and experiential level – they are charged with creating and fostering an interface between the disciplinary communities involved in their project – while the members of the scientific steering committee have the 'upstream' role of helping the GIS CES direction team to choose the projects to fund. The questions were formulated in a slightly different way for the project leaders and members of the steering committee, in accordance with their different roles. While interviewees hailed from a diverse array of disciplinary horizons, most of the scientists with an environmental sciences or modelling background claimed to have experience in interdisciplinary research. We will see later that this was influencing their representations of interdisciplinarity.

Table 2 Disciplinary backgrounds of the interviewees

Background disciplines	*Number of interviewees*
Environmental sciences	4
Modelling	3
Mathematics	2
Physics	1
Health	3
History	1
Economics	1

Table 2 highlights the numerical superiority of the 'hard' and environmental sciences (first four lines, in white) relative to social sciences and health (in grey). This is characteristic of the composition of the GIS CES, that includes more scientific laboratories than social and health research centres.

3.3 First data analysis by systematic coding

The second stage was a first analysis of the data from the interviews. While working with scientists from different disciplinary horizons, we made ourselves aware of the presence

and legitimacy of multiple perspectives, experiences and representations. In our analysis of the results, primary interest was put on the exploration of this diversity.

First, we classified the answers according to the questions' themes. Examples of questions' themes are: 'previous experiences', 'motivations', 'barriers', or 'surprises'. We kept track of the disciplinary origins of the quotes while classifying them under these themes. As the interviews have been run in French, we did an English translation, verified by an English colleague.

Under each theme arose categories corresponding to the various answers gathered. As an example, the categories were labelled 'positive' and 'negative' for the theme 'previous experiences'; and 'individual scale', 'project scale' and 'institutional scale' for the themes 'barriers' and 'facilitators'. The interviews were read twice: the first reading allowed for the coding of interviewees perspectives on interdisciplinarity, both in terms of their descriptive and normative claims. The second reading validated the regular use of the categories, and their completeness. At that stage, our analysis had the shape of a simple list of the motivations and objectives to commit to interdisciplinarity, the methods implemented, and the surprises, barriers and facilitators met by the various GIS CES projects.

Through this systematic coding we could reach a global vision of the interviews and it appeared that the themes were interrelated. Indeed, the analysis revealed links between the GIS CES scientists' previous experiences and their representations and definitions of interdisciplinarity, and highlighted how this background could influence the choice of the objectives and means to implement the interdisciplinary projects. Moreover, the systematic coding trigged the idea of pre-requisites; an idea which arose particularly from the 'methods', 'barriers' and 'facilitators' categories. In these categories, numerous normative quotes regarding the implementation and conduct of interdisciplinarity were noticed, translating the scientists' perception of key individual, group or institutional characteristics without which interdisciplinarity seemed hardly to occur.

However, as it emerged that the experiences, representations and actions of the scientists appeared to be interrelated, and the notion of 'pre-requisite' was trigged, we chose to not formally present these ideas to the GIS CES, but rather used them as a discussion point for the subsequent stage of the process.

3.4 First feedback from the GIS CES scientists and second data analysis

The third stage of the participatory action research was hence the presentation to the scientists of the interview results, alternating with our theoretical assumptions, at a GIS CES conference in May 2009. The presentation is available on the GIS CES website (http://www.gisclimat.fr/projet/ramons). During this conference, and a few days later through a survey sent per e-mail, the scientists had a chance to express their opinions on the accuracy and relevance of the first set of results.

The main output of this stage was the emergence for some GIS CES scientists, and reiteration for the others, of the idea of 'pre-requisite', that we already noted during the first analysis. Indeed, after the presentation, most of the scientists shared with us their feeling that some situational elements seemed to be key for the achievement of interdisciplinarity. The word 'pre-requisite' was commonly accepted, and its context-based nature acknowledged on both sides. This feedback allowed us to classify

our categories into four clusters, each representing a reflexive pre-requisite to interdisciplinary research, and labelled as follows in our second analysis:

a getting to know each other in the personal dimensions

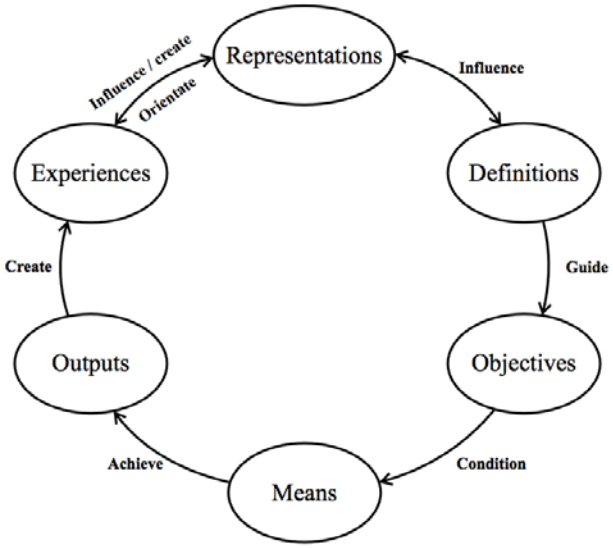
b getting to know each other in the disciplinary dimensions

c agree upon the definition of interdisciplinary research

d define collaboratively the purposes and means for the interdisciplinary project.

Another output of the GIS CES scientists' feedbacks concerned the clarification of the previously noticed links between experiences, representations and actions. Figure 1 illustrates these links that have emerged through the conference discussions and individual notes of the electronic survey.

Figure 1 Links between experiences, representations and actions



Of course, this figure could have been drawn differently, showing for instance more feedback loops between the experiences, representations and actions. However, it reflects the process of interdisciplinary research as perceived by the GIS CES scientists and by what we could observe from their current practices. The links between the different stages of interdisciplinary research provide a guiding line to the exploration of the four aforementioned reflexive pre-requisites. Indeed, according to what we could perceive in the GIS CES scientists' observations, (a) and (b) pre-requisites seem to foster the researchers and practitioners' reflections on their previous experiences, and how these may influence their representations on interdisciplinary research; for (c), researchers and practitioners explore both the complex origins of interdisciplinary science, and the influence of their representations on the definition they choose to give to interdisciplinarity; finally, the pre-requisite (d) appears to encourage the researchers and practitioners to make the objectives and mechanisms of their interdisciplinary project explicit. In this paper, we will follow this guiding line to discuss the four reflexive pre-requisites.

3.5 Second feedback from the GIS CES scientists and achievement of a consensus

The fourth and final stage of the participatory action research was a presentation and discussion of our second analysis, in July 2009. At that stage, we and the GIS CES scientists agreed upon the new formulation and classification of the reflexive pre-requisites to interdisciplinarity. However, we all acknowledged the fact that reflexivity as praxis largely transcends these four dimensions, and that a broader reflection on the current research modes should take place in order to have insights into the present mechanisms and potential facilitators of interdisciplinarity. But for the purpose of this paper, we choose to limit ourselves to what could be called a 'reflexivity limited in scope to the practice of team-based interdisciplinary research and its challenges'.

4 Results and discussions

This section explores the contributions of reflexivity to the launching and development of interdisciplinary research on climate change, by discussing the four reflexive pre-requisites in the light of the GIS CES experience. However, as noted in the introduction, these reflexive pre-requisites have no intention of universality; they are context-based and correspond to experiences, representations and expectations of GIS CES scientists, and to what we could perceive from the current GIS CES interdisciplinary practices. Hence, this section rather attempts a basis for discussions in other interdisciplinary contexts, fostering the evaluation of and reflection on the different paths to implement these cooperation dynamics.

4.1 First pre-requisite: getting to know each other in the personal dimensions

The first reflexive pre-requisite that arose from the interviews fosters members of a project to better know each other in the personal dimension; i.e., sharing and listening to each others' previous experiences, exploring each others' representations, and having a deep appreciation on the motivations that led GIS CES scientists to commit to interdisciplinary science.

4.1.1 Previous experiences and representations

As shown by Figure 1, previous experiences of researchers and practitioners involved in an interdisciplinary project seem to influence the way they represent and define interdisciplinarity. For instance, Bramsnæs et al. (1997) found that researchers with experience in working across disciplinary boundaries find the first time is more difficult and takes more time than following projects. This is why Creutzer (2002) emphasises the importance of reflecting on the origins of the commitment towards interdisciplinarity, and questioning the previous experiences that may have led to it. If the previous experiences are not made explicit, representations of interdisciplinarity may be misunderstood among researchers involved in a same project.

The analysis of the interviews highlighted three kind of previous experiences, that seemed to influence the GIS CES scientists' representations. The first one is that of

interdisciplinary background. For scientists with a university degree in climatology or environment, interdisciplinarity is natural, logical and necessary: "I have the feeling of being born within interdisciplinarity. I couldn't imagine working according to another method". For them, the legitimacy of interdisciplinarity is obvious in everyday research; scientists assert they have 'no choice'. Research processes also lead GIS CES scientists to work within, or evolve towards, interdisciplinarity: "For the PhD, we are working on specific topics. But as we evolve in our research, we feel the need to enlarge our field of action and explore other methods, other topics". As the interdisciplinary step is necessary to tackle a complex theme, researchers with an interdisciplinary background seem to continue along that path, and represent interdisciplinarity as a natural and essential way of working.

Experiences of failures constitute a second kind of previous experiences that appears to guide the scientists' representations on interdisciplinarity. Failures are experienced relative to the current research modes: "We experience a hyper-specialisation of research, but I don't want to be locked up in a single discipline during my entire career". Curiosity and interest for other modes of constructing the knowledge lead scientists to open up to interdisciplinary research dynamics. Disappointments are as well expressed regarding the discipline of origin; the lack of openness to other disciplines or social and political spheres is especially criticised: "In history, we have a ghetto culture; we feel we don't need to communicate with others". This was observed as well by Caldwell (1983) who assumed that interdisciplinary approaches arise because of a perceived unfitting among needs, information, and the structure of knowledge inherent to disciplinary organisation. These experiences of disappointment translate to a wish to take distance from the discipline of origin, and guide scientists towards interdisciplinarity.

In a reciprocal way, the third kind of experiences modifying the GIS CES scientists' representations of interdisciplinarity is the successful experiences: "Every time I have collaborated with people from different universes, we progressed really quickly, and in very surprising and enriching ways". The positive experiences drive scientists to continue along the route of interdisciplinarity, because they bring a new vision of a problem; enrich the exercise of knowledge building and the knowledge itself.

4.1.2 Motivations

Motivations for committing to an interdisciplinary project are associated with how researchers and practitioners define and represent interdisciplinarity, and how they understand its origins. Therefore, being reflexive on and sharing motivations for committing to interdisciplinarity might allow group members to better harmonise their goals and objectives. If the motivations are not made explicit, researchers or practitioners may raise conflicting objectives that will curve the progress of the interdisciplinary project. Klein (1996) distinguishes six main categories of motivations leading to interdisciplinarity. These include:

1 the resolution of complex cross-problems

2 a desire to frame science within a social context (or to redefine the role of science in society)

3 the reconciliation of the mass and elitist cultures

4 the creation a new scientific field or redefinition of an existing field by overcoming the disciplinary frames

5 education

6 inter-institutional alliances for giving effect to change in the political and disciplinary scales.

On the other hand, Creutzer (2002) proposes an organisation of the motivations around two poles: the social and epistemological poles. The social pole tends to redefine the role of science within society. At the other end of the scale, the epistemological pole attempts to achieve a certain unity of science; to better understand complexity, or to improve comprehension at the boundaries of disciplines for example. There are near infinite possible motivations along the scale between those two poles.

To analyse the interviews, we have chosen to combine the classifications of Klein (1996) and Creutzer (2002) to emphasise the need of situating the motivations along the line of the two poles. The interviewees pointed four main kinds of motivations.

One set of motivations is situated around the epistemological pole. These are expressed by a desire to restructure and better network the scientific fields to respond to complex problematic. The GIS CES scientists showed a willingness to generate new synergies between disciplines, implement a 'shared culture', an 'interface where different communities can discuss about complex issues'. Structuring scientific communities is a means to approach complexity: when researchers or practitioners face methodological barriers or knowledge gaps, interdisciplinarity allows them to have a broader and deeper understanding of the problem. Contributions in terms of methodology is another motivation: "being inspired by data, results, or the thinking processes of other disciplines helps us to design more effective and comprehensive approaches to complex topics". Finally, GIS CES scientists commit to interdisciplinarity as well for the uniqueness of the scientific results that arise of a project.

The second kind of motivations is linked with the social pole. They mainly find expression in the willingness of the scientists to open their discipline to socially rooted questions. The feeling of being useful for society is an important motivation as well: "Linking my scientific problematic to social aspects reminds me why I am a researcher". Interdisciplinarity is thus considered as a means to reflect on the role and responsibilities of science regarding the social and political spheres.

A third set of motivations is a combination of social and epistemological reasons, and concerns the win of credibility through interdisciplinarity. It is exhibited at three different levels: disciplinary, socio-political and international. Firstly, integrating different disciplines help researchers to 'reinforce the qualitative data from the medical, historical or social fields, with quantitative data from physics or the natural sciences', and allow their contextualisation through multiple perspectives and constructions. Second, being credible can be translated by the achievement of an effective social or political message. The GIS CES scientists express the wish to take part in a movement responding to the fears of policymakers and society, through scientific collaborations that strengthen the nature of the results and give them more depth. Finally, the third-level motivation is a desire to be at the core of interdisciplinary dynamics at a larger scale: "Our project will be credible if it allows other interdisciplinary projects to take root in our experience and results". Indeed, if the current GIS CES projects form the bases for future projects at a

larger European-wide or world-wide scale, to address a broader social demand, it makes them credible and effective, particularly for the funding authorities.

The fourth and last category of motivations gathers together the personal interests of GIS CES scientists. Interdisciplinary projects allow them first to learn about their own discipline and contextualise it in the scientific landscape by comparing methods, tools or thinking processes used by other disciplines: "We have different ideas, we prioritise variables according to different criterions, and we represent processes or phenomenon in different ways". Integrating the vision of another discipline seems to encourage the scientists to take distance on their discipline, and reflect on its origins, contours, modes of producing knowledge, and capacities to interact with other disciplines or with the socio-political sphere. Attempting to understand other thinking processes may allow researchers and practitioners to implement changes in their own discipline; towards more openness, flexibility, and a more effective and global understanding. The GIS CES scientists also commit to interdisciplinary projects to satisfy a curiosity; they want to experience the interdisciplinary process: organisation, collaboration, and debates. Tackling a complex theme through an interdisciplinary approach allows researchers to go out of their usual research field, or at least to approach it from a different angle; interdisciplinarity is an original way of doing research, considered for some GIS CES scientists as entertaining.

To sum up, the motivations of the GIS CES scientists are situated both around the social and epistemological poles, without an explicit placing of the 'cursor'. This step of sharing previous experiences, representations and motivations is not often given deep expression, because it takes time. Nevertheless, GIS CES scholarship showed that it seems essential to achieve an interdisciplinarity project. First, sharing previous experiences and representations fosters respect and comprehension; pillars without which deep interdisciplinary cooperations would probably struggle to exist. Second, unexeplicated motivations seem to lead to misunderstandings within the selection and building of projects; for instance, it took one year for the medical doctors to 'finally understand the objectives of the physicists'.

4.2 Second pre-requisite: getting to know each other in the disciplinary dimensions

According to the GIS CES experience, the second reflexive pre-requisite appears to be facilitated by the first one: meeting each other in the personal dimensions. Indeed, getting to know each project member allows the creation of an area of trust and understanding, which favours lively discussions and self-disclosure. In the interviews, there were numerous references to persons or disciplines with who GIS CES members were collaborating. Words or notions from other disciplines were adopted as well, and integrated in the discourses: "For the measures on our patients, we will use spectro-radiometers or pyrometers; we tested these tools with the physicists, they are reliable". This is a sign of recognition; people acknowledge that the contributions of the others are necessary to the elaboration of their personal thinking. This atmosphere fosters the project members to interact on respectful and free bases. Through the questions, observations, and critiques of the project members, each one individually is encouraged to reflect, take distance, and put into questions its own discipline.

The second reflexive pre-requisite concerns the meeting of project members in the professional dimensions, and their understanding on how disciplinary culture might

influence interactions and representations of interdisciplinary research. Indeed, Brewer (1999) affirms that people who do interdisciplinary work confront obstacles such as different cultures and frames of reference, different methods and objectives, and different languages. To illustrate the challenge of communicating across disciplines, Klamor and Leonard (1994) assert that scientists express themselves through metaphors, progressing in degree of complexity from the merely pedagogical, through the heuristic, to what they call constitutive metaphors. At the first two levels, the meanings are relatively visible. They help connect new situations with existing knowledge. Metaphors of the constitutive type are difficult to see because they form the very context of the science. Constitutive metaphors often become invisible to the practitioners of the science and generally provide foundations that are rarely challenged – they define constellations of maintained hypotheses as well as methodological norms, that are necessary to focus the work of the discipline (Wear, 1999). If sometimes transparent to practitioners, constitutive metaphors can be completely invisible to outsiders. The fundamental challenge to interdisciplinarity is hence the communication of the different ways we see the world, that is, our constitutive metaphors. The greater the divergence between these foundations, the more difficult it is for communication to be effective. Therefore, the willingness to learn each other's language, methods, tools and results in another discipline seems to be the basis to a cross-disciplinary dialogue, and thus the first step to the construction of an interdisciplinary project (Hunt, 1994). Bauer (1990) goes on and asserts that a requirement for successful interdisciplinary science might be the acknowledgement that each discipline has an appropriate and necessary role.

These insights given by the literature emphasise the need for interdisciplinary project members to take distance on their discipline, and on the constitutive metaphors they use. Particularly, according to the GIS CES experience, the second reflexive pre-requisite is composed of three stages, all expressing the need for making the constitutive metaphors, or 'the ways to see the world' explicit. The first issue to discuss is that of language. To avoid misunderstandings in the creation and concrete implementation of the project, it seems important that project members learn about, compare and discuss key concepts, approaches, and tools used by the different disciplines involved. This might allow them to clarify which approaches or tools are the most relevant to tackle their cross-problematic. Second, the functioning, i.e., the values and rules of the disciplines involved, has to be made explicit to understand the relationships between them. For instance, it appears useful to reflect on the hierarchy of the disciplines within the scientific landscape, and try to understand why it exists as it is, and how this might influence cross-collaborations. As well, it seems important to explore the procedures for creating and validating knowledge and rewarding scientists, in order to discuss the practical aspects of interdisciplinary publications. Third, the complexity and probable obstacles of working with different kinds of data should be highlighted, in order to find complementarities, and reflect on their integration and harmonisation. Indeed, data have different natures (qualitative or quantitative), a different accessibility, and various spatial and temporal scales depending on disciplines. For instance climatologists have an 'impressive mass of data coming out of their models', that are 'easily available on internet', whereas historians have to 'meticulously read through a hundred of parish registers and not even be sure to find concluding results'. Another example is given by soil scientists and climatologists, for whom the challenge to find a common spatial scale

was daunting: 'after a long period of reflection and debates, we made the compromise to work at the parcel scale'.

To help structuring the dialogue, simple tables that compare the linguistic habits, values, and data of each discipline involved in a project could be used. They might help members of a project to evaluate these difficulties that are major issues in interdisciplinarity by making the eventual tensions, blocks, and convergence points explicit. They might as well guide the members to decide how much time they need for getting to know each other enough to draw a coherent interdisciplinary project.

In conclusion, the second reflexive pre-requisite, that encourages researchers and practitioners to take distance from their own discipline and the constitutive metaphors that define it, and to acknowledge the influence of their home discipline on the relation to others, seems to facilitate the openness to cognitive and social matrices constituting the various disciplines that meet. But this second pre-requisite appears to be not only essential for implementing an interdisciplinary project; it might as well be a step that transforms the scientific landscape. As Hunt (1994) observes, "once the language of the other discipline is learned, the relationship to the home discipline is never again the same". Indeed, the interdisciplinary co-construction of knowledge seems to have repercussions in the various disciplines involved in the project, thus instilling changes to the scientific research towards the integration of different kinds of knowledge; a necessary step to respond to social expectations towards climate change.

4.3 Third pre-requisite: agreeing upon the definition of interdisciplinarity

When researchers and practitioners have created an area of trust, respect and understanding, and have collaboratively taken stock of the uniqueness and relevance of every discipline involved, the third reflexive pre-requisite to interdisciplinary research emphasised by that GIS CES scientists is to reflect and agree upon a definition of interdisciplinarity, and hence take insights into its origins and foundation statements. The GIS CES experience illustrates hereunder the kind of misunderstandings and conflicts that can arise from an absence of reflection on the origins and definition of interdisciplinarity, and thus shows how and why the GIS CES scientists emphasised the importance of the third pre-requisite.

The twofold analysis of the interviews revealed four defining dimensions of interdisciplinarity. Firstly, and perhaps most obviously, GIS CES scientists saw the meeting of several disciplines around a common topic as the basis to interdisciplinarity: "interdisciplinarity allows the study of an object that doesn't fit in the field of a single discipline". As all the GIS CES scientists seemed to acknowledge this aspect of interdisciplinarity, an effort was made in every project to collaboratively draw a cross-problematic, that required the perspectives of several disciplines for its understanding.

A second dimension that was frequently raised by the GIS CES scientists is that of distance between disciplines. For most scientists, "interdisciplinarity is working with people coming from different disciplinary fields", where "nobody is accustomed to working together". Hence, cooperation between 'close' disciplines, i.e.; whose cognitive and social matrices are similar, was not perceived as interdisciplinary by the GIS CES scientists, for the reason that they did not distinguish strong challenges regarding the language or the valorisation of the work. Yet, according to the literature (see Section 2), interdisciplinarity does not seem to be linked with the notion of distance between

disciplines. For instance, interactions between chemistry and biology, whose cognitive and social matrices have numerous common features, still appeal for a common construction of the inquiry, a sharing of tools and methods, and hence, an explication of the constitutive metaphors of the disciplines involved (Knorr-Cetina, 1995). As disciplines have different attitudes toward truth, and different opinions regarding what knowledge is valuable, not considering that interactions between 'close' disciplines are interdisciplinary might result in an absence of reflection on how to cooperate, and may thus lead to misunderstandings in the construction of the inquiry, in the choice of the means, and in the nature of the results to achieve.

A third notion of interdisciplinarity that was acknowledged by the GIS CES scientists is that of dialogue for co-construction. According to them, the co-construction of an interdisciplinary project has to occur 'from its early stages, and during all the project', in order to establish "discussions and debates among the project members, regarding the methodology, tools, timetable, resources, and so on". Mediation might thus highlight the needs and expectations of each participant in a project. In the GIS CES, only few projects had formalised their dialogue for co-construction, resulting in misunderstandings regarding the means and aims for most of the projects.

Lastly, the notion of reciprocal contribution was raised. It will be seen later that those rewards are represented in terms of personal enrichment, sharing in the networks of colleagues, and increasing the speed of the project. Most of the GIS CES scientists were conscious of these rewards, and expressing a curiosity towards other disciplines' methods and results. According to the scientists, "this interest was a motor facilitating the informal interactions between project members", and amplifying their wish to work together and 'meet on a frequent base'.

According to the literature, the four notions highlighted by the GIS CES scientists are foundational to a definition of interdisciplinarity. However, noticeably absent was the notion of sharing of tools and methods. This notion was raised by the scientists in defining transdisciplinarity. Rather, most participants conceived interdisciplinarity as a dynamic of cooperation that involves, in turn, the social and cognitive matrices of each disciplines involved, i.e., without any real transgression of the disciplinary boundaries.

To sum up, the GIS CES experience shows that through clarification of the notion of interdisciplinarity and its origins, researchers and practitioners could structure the interactions between disciplines in a more systematic way, mediate between the multiple perspectives, representations, expectations and needs, and better valorise the interdisciplinary outputs; this in order to construct a more coherent project, potential basis or reference for future interdisciplinary interactions.

4.4 Fourth pre-requisite: defining collectively the purposes and means of the interdisciplinary project

The contextual nature of interdisciplinary dynamics makes it difficult to follow any means of 'best-practice'. Hence, nearly infinite objectives and means exist to accomplish an interdisciplinary project, which depend on the project's structure and design: the scope, size, and political context of the project, as well as differences in national culture (Jakobsen, et al., 2004). For instance, Hatch (1997) assumes that a bigger group makes it more likely for sub-groups to form, and thus hinder the interdisciplinary dynamic at the project scale. However, as seen above, the literature proposes six main

purposes to interdisciplinary science: education, problem solving, new research fields, inter-institutional alliances, social contextualisation of science, or the crossing of the boundaries between the scientific and local culture (Klein, 1990), that can be classified according to social or epistemological considerations. If interdisciplinarity seems first of all to be a set of epistemological questions, seeking a more comprehensive understanding of a complex topic, it appears to deeply be as well a question of facing the problems coming with the modernisation of the life frame. Interdisciplinarity explains itself with the fact that science, like other types of knowledge, contributes to the representation of the world with which we can draw up solutions to our difficulties.

Hence, according to the GIS CES scientists, the fourth and last pre-requisite to interdisciplinarity that researchers and practitioners should explore are the definition and organisation of means and purposes to implement interdisciplinarity, which are adapted to their particular project context. Indeed, in the absence of such clarification, researchers and practitioners may experience some difficulties in defining the methods to achieve their objectives. In the GIS CES experience, the purposes were found to manifest themselves around the two poles, often within the same project, but their existence or co-existence was not made explicit by the GIS CES scientists.

Purposes around the epistemological pole were translated by the GIS CES scientists as a feeling of inadequacy of their own discipline, particularly when they had to understand the complexity of a cross disciplinary problematic and/or improve comprehension at the boundaries of the disciplines: “Our goal is to model the relations between the ocean, atmosphere and ecosystems. Thus, it is necessary for us to integrate physics, chemistry and biology”. For many scientists, interdisciplinarity is as well natural and essential because of the complex nature of their research themes: “When a topic is situated at the boundaries of the disciplines, we need to work with others. We need their expertise and perspective”. Beyond enrichment in terms of knowledge and methods, the epistemological purposes expressed themselves in terms of competences and attitudes. The scientists showed a willingness to explore new methods for integrating different disciplines: “What I mainly expect from the projects are ways of structuring scientific communities in the long run: we need to implement durable systems of exchange”. Indeed, GIS CES projects are often considered as testing grounds for learning how to implement interdisciplinarity, and to potentially constitute references for future interdisciplinary projects. Lastly, the epistemological purposes were communicated by GIS CES scientists as a means of validating their results: “In the literature of medicine most of the studies are based on questionnaires, the results of which are sometimes unreliable. Thus our idea is to transform the physical data into exploitable data for the epidemiologists”. This willingness to reinforce the strength of the data and make them more reliable by adding the viewpoint of another discipline equates to the underlying goal of achieving a unity of science.

Purposes around the social pole found expression particularly in a desire to respond to a current social need, or help society plan for future challenges: “I hope that our results will help the agricultural communities of West Africa to better plan their harvests”. Indeed, the ‘health’ and ‘adaptation’ components of GIS CES’s work open the natural scientists to socially rooted questions. The social purposes appeared as well through the willingness to contribute to an effective political message: “The message of the dermatologists is confused by the beauty industry. Thus, through collaborations with the physicists, we want to achieve a strong message, because what we are saying now is ineffective”.

The GIS CES experience shows that the coexistence of social and epistemological purposes within a same project often leads to misunderstandings and disagreements over its ends, and over the means to such ends. For instance, means and ends were confused in a project studying the impacts of climate change on skin cancers: while physicists claimed: "The goal of our project is to facilitate the dialogue between scientists and the general public, about public health"; the medical doctor considered this objective rather as a means to achieve better prediction and prevention policies: "If we achieve a better interface between our scientific community and society, we will be able to work together to increase awareness of policy-makers and society regarding skin cancers". Because of these misinterpretations and lack of previous explication of the project members' expectations, GIS CES scientists often had to come back to an early stage of the project, make their motivations regarding the objectives explicit, and debate and agree-upon them.

5 Conclusions

The four reflexive pre-requisites, formulated through our participatory action research process with the GIS CES scientists, bring two main results to light. First, they allow context-based insights into the contributions and innovative ideas brought by reflexivity to the long-lasting implementation and conduct of interdisciplinarity. Specifically, the pre-requisites have asserted the importance for researchers and practitioners involved in interdisciplinarity to reflect on, share and discuss their habits, values, rules, epistemologies, and personal interests – in other words, their constitutive metaphors and their social and epistemological matrices, which influence their vision of the world, and guide their way of doing research. Second, the pre-requisites have underlined that being involved in a cross-disciplinary dialogue appears to foster scientists to reflect, question and take distance on their own discipline; revealing the intertwined and evolving nature of the relationship between interdisciplinarity and reflexivity. These two outputs might constitute, for researchers and practitioners coming from diverse research contexts, a starting point to leading reflections and discussions on the various ways to implement interdisciplinary dynamics.

To bring more structure to these reflections on the links between interdisciplinarity and reflexivity, the ongoing interactions with the GIS CES have allowed the elaboration, testing and improving of two concrete tools to help researchers and practitioners to implement reflexivity for interdisciplinary science. First, to avoid 'reinventing the wheel at each new project, at each new problematic', which is a frequent problem, documentation on the construction and evolution of the collective dynamics within a group in a logbook seems to be useful. The GIS CES experience has shown that holding a logbook encourages researchers and practitioners to come back to previous steps of the project, and change their orientation if necessary; constituting precious roadmaps for future projects or other researchers. Furthermore, it fosters researchers and practitioners to lead a constant and explicit reflection on the interactions between the group members and on the impacts of the projects on the problematic explored. The reflexive step through logbooks allows as well researchers and practitioners to be aware that an interdisciplinary project is evolving over time, meaning they should reflect on 'alternative means that help the project adapt to new settings', and achieve its objectives.

Second, in the same perspective, writing breaks in the middle of interdisciplinary meetings were proposed within the GIS CES context, to allow researchers and practitioners to put order in the abundance of ideas that have been developed through cross-disciplinary discussions, and leave them time to pursue alone and expand what has been trigged by the others in the debates. Indeed, interdisciplinary cooperations generally open on a multiplicity of possible paths, arising from the diverse interpretations and perspectives involved. The proliferation of ideas is simultaneously desirable and a vector of confusion (Jollivet-Blanchard and Blanchard, 2004). Accordingly, it seems essential to not leave this proliferation of ideas unstructured. Writing first allows researchers and practitioners to take distance on the proliferation of ideas, and second to organise the ideas that have found echo in themselves, as contributions, impressions, or questions. Writing is a necessary break to not get lost in the oral interventions. The cooperative step is physically interrupted, but goes on symbolically, giving each project member the time to appropriate the generated knowledge and ideas by transcribing them in their own words.

Finally, a third tool designed to foster and structure reflexivity for interdisciplinarity, but that has not been applied yet within the GIS CES context, is the use of constitutive metaphors. The reflection on and sharing of constitutive metaphors allows, according to Ferris (2003), Klein (2004), and Klamor and Leonard (1994), the representation of disciplines and their links in an integrated way. Hence, the use of metaphors might allow researchers and practitioners to pursue a reflection on the situated nature of the knowledge they produce. The recognition that knowledge is achieved within socially-constructed frames, and to some extent based on personal experiences and expectations, could favour disclosure, openness and interest towards modes of inquiry and results originating from other disciplines.

Acknowledgements

The authors wish to thank the Scientific Consortium for Climate, Environment and Society for its financial support through the RAMONS project and for the access given to the interviewees. The authors thank as well the interviewees for their participation.

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