Reflexive interdisciplinarity

Supporting dialogue on the role of science for climate change

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Abstract

This PhD dissertation is about interdisciplinarity for climate change; a research dynamic that has found a very broad expression in the literature, especially since the 1980s. With the growing popularity of interdisciplinarity among scientific organisations and their funding institutions, a heavy literature has risen, with at times fuzzy and at times conflicting definitions of the concept. Against this background, it becomes difficult for researchers and practitioners involved in interdisciplinary initiatives to navigate in such complexity, and give rise to 'authentic interdisciplinarity'.

This PhD therefore tries to better understand how cooperations across disciplinary boundaries emerge and develop. More specifically it proposes an emphasis on reflexivity, in the sense of individual and collective scrutiny of the personal as well as disciplinary assumptions, motivations and interests, to facilitate innovative and authentic interdisciplinarity. Beyond this pragmatic objective, the exploration of interdisciplinarity for climate change allows for critical discussions on the role and organisation of science for this issue.

The dissertation builds upon participatory action research undertaken over the period 2008 - 2010, within the Parisian Scientific Consortium for Climate, Environment and Society (GIS CES); an institution in charge of facilitating, supporting, funding and coordinating interdisciplinary research on the impacts of climate change on the various social, economic, political and environmental spheres. The PhD is structured around four stand-alone papers, linked together by an introduction.

Paper 1 aims at achieving an increased understanding of interdisciplinarity, by (a) defining and framing it aside other research types, from disciplinarity to transdisciplinary approaches;

(b) highlighting its key constitutive dimensions; and (c) providing insights into its origins and history. It thus follows the action-driven objective of providing the interested actors with a clearer map of interdisciplinarity, and suggested guidelines for its concrete implementation. Paper 2 attempts to evaluate the ways in which reflexivity contributes to the emergence and development of interdisciplinarity, especially when the reflexive step is implemented at the early stages of an interdisciplinary project; i.e., when its objectives, means and resources are not yet definitively established.

Paper 3 expands on Paper 2 by presenting a model of long-term reflexive interdisciplinarity for climate change, guided by an authentic and reciprocal dialogue between scholars of Science and Technology Studies (STS) and climate-related scientists, and articulated around four reflexive tools: 'inaugural contracts', 'harmonised presentations', 'summary tables', and 'writing pauses'. This model allows for a critical questioning of the current practices and organisation of science for climate change.

Finally, Paper 4 seeks to bridge the perspectives offered by the STS literature on the science-policy interface for climate change, and by climate-related scientists active at this interface. It identifies some important discrepancies regarding the representation of climate change, leading to divergent discussions of the interactions and actions at the interface. Paper 4 thus argues in favour of a reflexive dialogue between STS researchers and scientists to collectively frame this interface.

The main conclusion of this PhD is that reflexivity seems to bear important contributions to the implementation of 'authentic' interdisciplinary research for climate change. However, like interdisciplinarity, reflexivity is a long-term learning process, which represents an investment in time and energy. We thus assert that the current organisation of research in Europe, following principles of management, efficiency, prestige, competition and hierarchy, is poorly adjusted to interdisciplinary and reflexive science. We advocate for a dialogic rethinking of the current practices of science for climate change, as well as the science-policy interface, with regard to the complexity, uncertainty and plurality of legitimate perspectives surrounding this issue.

Résumé

Cette thèse de doctorat porte sur l'interdisciplinarité mise en œuvre dans le cadre de problématiques en lien avec le changement climatique. L'interdisciplinarité a trouvé une expression très large dans la littérature, particulièrement depuis les années 1980, avec la reconnaissance grandissante des changements environnementaux planétaires et de leur nature complexe et incertaine. Cependant, l'engouement des organisations scientifiques et de leurs institutions fondatrices pour l'interdisciplinarité a contribué à l'émergence d'une littérature dense, vecteur d'une profusion de définitions variées, et souvent conflictuelles, du concept. Il est ainsi difficile pour les chercheurs et praticiens impliqués dans des initiatives interdisciplinaires de naviguer dans une telle complexité, et de mettre en œuvre des pratiques 'authentiques' d'interdisciplinarité, garantes à la fois de résultats scientifiques innovants et de changements de postures de recherche vers une attitude plus coopérante, réflexive, critique, ouverte, hétéro-centrée, et flexible.

Dans ce contexte, cette thèse cherche à mieux comprendre comment émergent et se développent les coopérations au-delà des frontières disciplinaires. Ainsi, nous proposons, afin de faciliter leur mise en œuvre, de relier de façon innovante l'interdisciplinarité au concept de réflexivité ; la réflexivité étant comprise ici comme étant un questionnement et une analyse pluriels des représentations, des présupposés, des motivations et des intérêts personnels et disciplinaires. Au-delà de cet objectif pragmatique, l'exploration de la question de l'interdisciplinarité permet de structurer un ensemble d'arguments critiques sur le rôle, les contributions et l'organisation des sciences du climat (au sens large) dans le contexte du changement climatique.

La thèse s'appuie sur une recherche-action participative menée sur la période 2008-2010 au sein du Groupement d'Intérêt Scientifique pour le Climat, l'Environnement et la Société (GIS CES) d'Île-de-France. Le GIS CES est chargé de financer, de faciliter et de coordonner des recherches interdisciplinaires concernant les impacts du changement climatique sur les sphères sociales, économiques, politiques et environnementales. Cette institution s'appuie sur l'expertise d'un ensemble de laboratoires de recherche travaillant principalement dans les domaines de la climatologie, de l'hydrologie, de l'écologie, de la santé et des sciences humaines et sociales (incluant l'économie environnementale, l'économie écologique et l'histoire).

La thèse suit le format recommandé par l'Université de Bergen (Norvège) : elle est structurée autour de quatre articles autonomes, publiés ou en cours de publication, reliés, harmonisés et contextualisés par une introduction.

L'article 1, basé sur un parallèle entre littérature et pratique, répond à un objectif pratique : celui de 'dissiper la complexité autour de l'interdisciplinarité'. L'intention sous-jacente étant d'épauler les chercheurs et les praticiens dans la construction et le développement de leur projet interdisciplinaire, en leur fournissant une carte claire et globale du concept ainsi que des suggestions pour sa mise en œuvre concrète.

Pour effectuer cette mise à plat « structurante », l'article propose une *définition de l'interdisciplinarité en trois volets*. Premièrement, l'interdisciplinarité est définie par rapport à trois autres dynamiques de recherche basées elles aussi, à divers degrés, sur des interactions entre disciplines variées : la pluridisciplinarité, la multidisciplinarité, et la transdisciplinarité. Ces divers concepts étant souvent utilisés de façon interchangeable dans la littérature et parmi les praticiens, le premier volet de la définition contribue à éviter les confusions. D’une part, en rappelant la nature coopérante, réciproque et évolutive des interactions interdisciplinaires, qui diffèrent ainsi de la pluridisciplinarité et de la multidisciplinarité. Ces dernières sont en effet des pratiques restreintes au seul partage du sujet de recherche, en plusieurs éléments distingués les uns des autres, sans aucune organisation coopérante pour établir des liens entre eux. D’autre part, contrairement à la transdisciplinarité qui est synonyme de création d’une nouvelle discipline adaptée à l’étude d’un sujet émergent complexe, l’interdisciplinarité, quant à elle, créé de nouveaux outils et de nouvelles approches en croisant l’expertise de plusieurs disciplines, sans pour autant construire une méta-discipline. Par contre, les savoirs et savoir-faire construits au tout long du processus interdisciplinaire seront en retour mobilisés dans les diverses disciplines et participeront à leur développement.

Le deuxième volet de la définition de l’interdisciplinarité met en évidence ses principales dimensions : la réflexivité et l’authenticité, considérées dans l’article 1 comme les pierres angulaires de l’interdisciplinarité. En effet, nous postulons l’idée selon laquelle l’effort de réflexivité dont l’objectif est une meilleure connaissance de soi (de ses présupposés, ses expériences, ses motivations et ses intérêts) ainsi que de sa propre discipline (ses perspectives ontologiques, épistémologiques et méthodologiques), encourage et facilite les interactions authentiques au-delà des frontières disciplinaires. En retour, l’authenticité du dialogue avec les partenaires, son honnêteté et son respect, encouragent les remises en questions personnelles, qui elles-mêmes facilitent les interactions interdisciplinaires. En effet, la réflexivité, en permettant à chacun de prendre conscience des imperfections, des faiblesses et des limites de sa discipline, entraîne par ricochet la reconnaissance de l’autre. Il est alors plus aisé de reconnaître le besoin de coopérer avec les autres disciplines sur un sujet complexe, pour lequel sa propre discipline ne peut apporter toutes les réponses.

Enfin, le troisième volet de la définition de l'interdisciplinarité porte sur ses origines et son évolution historique. Ainsi, d'après la littérature, l'interdisciplinarité est légitimée par la reconnaissance du fait que certains objets d'étude, le climat par exemple, n'appartiennent pas à une seule discipline spécifique, mais sont nécessairement intégrés à plusieurs disciplines, et ne peuvent être étudiés, par conséquent, qu'à travers une perspective interdisciplinaire. Ce n'est alors qu'à travers un faisceau de perspectives disciplinaires que le savoir créé sera légitime, et qu'il pourra être mobilisé par les acteurs socio-politiques pour la prise de décision.

L'article 2 dresse un premier état des lieux des apports de la démarche réflexive dans le cadre de la mise en place de coopérations interdisciplinaires authentiques. Pour cela, nous nous appuyons sur une recherche-action participative menée au sein du GIS CES, qui a révélé des échecs dans le développement interdisciplinaire de certains projets. L'étude spécifique de ces projets en situation d'échec nous a permis de dégager des enseignements quant à la notion de coopération entre les disciplines. Nous avons en effet observé plusieurs divergences majeures entre les acteurs d'un même projet ; des divergences liées à la définition de l'interdisciplinarité, aux intérêts personnels et aux contributions des disciplines participantes. Ces interprétations différentes restées inexpliquées, ont par la suite provoqué des malentendus quant aux objectifs des projets et à leur déroulement. Elles ont empêché la mise en œuvre de coopérations interdisciplinaires réelles et durables.

Ce constat nous a conduits à souligner l'importance déterminante de la *phase de construction* des divers projets interdisciplinaires. En effet, ce sont lors de ces étapes initiales que se décident les objectifs, les moyens et les ressources des projets, ainsi que la nature des interactions. Cependant, c'est à ce même stade que le désengagement des acteurs est le plus fort : ils peuvent, en effet, être surpris par la complexité et les incertitudes inhérentes aux contextes interdisciplinaires, ou avoir le sentiment que leur expertise n'est pas suffisamment prise en compte. Parce que les premières étapes d'un projet conditionnent en partie son succès, nous explorons, dans l'article 2, les façons dont la réflexivité, lors de ces étapes initiales, contribue à l'émergence et au développement de l'interdisciplinarité.

La recherche menée au sein du GIS CES nous a permis de mettre en lumière *quatre prérequis réflexifs*, donnant l'opportunité aux acteurs de constituer le cadre d'un contrat inaugural pour mettre en œuvre un projet interdisciplinaire :

(a) Se rencontrer, et tenter d'expliciter ses propres expériences et ses représentations sur l'interdisciplinarité, ainsi que ses propres motivations pour le projet;

(b) Connaître les univers disciplinaires de chacun afin d'envisager les chemins vers un travail collectif;

(c) Définir de façon coopérative l'interdisciplinarité, et clarifier ce que cette définition implique en termes de valeurs de recherche;

(d) Définir de façon coopérative les objectifs du projet et les procédures à mettre en place, en prenant en compte les trois points précédents.

L'article 3, s'inspirant des résultats de l'article 2, met en avant les contributions d'une démarche de réflexivité sur le long terme : qui va au-delà de la phase de construction du projet. En effet, parce que les acteurs d'un projet interdisciplinaire évoluent grâce aux interactions collégiales, mais aussi parce qu'ils sont confrontés à différents défis émergeant au cours du processus, l'effort de réflexivité doit être poursuivi tout au long du projet, afin de permettre des réajustements en termes d'objectifs ou de structures.

Notre recherche-action participative a ainsi révélé l'existence de six principaux défis pour la mise en œuvre de l'interdisciplinarité dans le contexte du changement climatique. Ces défis peuvent être définis comme étant des exercices d'équilibre entre les spécificités souvent antinomiques inhérentes à l'interdisciplinarité. Les acteurs de projets interdisciplinaires doivent en effet jongler entre différence et complémentarité, évolution personnelle et authenticité, créativité et dépendance, incertitudes et innovation, réflexivité et désillusion, apprentissage et efficacité. Face à ces défis, la réflexivité joue un rôle stabilisateur, aidant les acteurs à gérer leur projet interdisciplinaire avec plus de sérénité.

Sur la base de ces six défis, l'article 3 présente un modèle pour une interdisciplinarité réflexive de long terme dans le cadre du changement climatique. Ce modèle, applicable à d'autres initiatives interdisciplinaires, est articulé autour de *quatre outils réflexifs* :

1. Un 'contrat inaugural', signé par les acteurs d'une projet interdisciplinaire, et leur offrant l'opportunité de définir les rôles de chacun, les objectifs et les moyens du projet, ainsi que les règles de coopération ;

2. Des 'présentations harmonisées', au cours desquelles les acteurs exposent leur perspective sur la problématique à l'aide d'un support standardisé (organisé autour des mêmes titres, questions et structure), permettant ainsi d'établir un parallèle direct entre les disciplines ;

3. Des 'tableaux synthétiques', guidant les acteurs dans leur compréhension des autres disciplines, en proposant une exploration structurée selon les outils, données, échelles, ou encore règles de fonctionnement des disciplines ;

4. Des ‘pauses écrites’, organisées de manière à offrir du temps aux acteurs de projets interdisciplinaires dans le but de prendre de la distance sur eux-mêmes, sur leur discipline, ainsi que sur le projet.

Nous avons observé, au cours de notre recherche action participative, que ces outils posent les bases d’une reconnaissance de la légitimité des diverses perspectives disciplinaires. Dans un même temps, ils engagent chaque acteur dans une démarche de prise de conscience et d’acceptation de la complexité inhérente tant à la problématique qu’au processus.

Néanmoins, parce que l’interdisciplinarité et la réflexivité sont des processus de long terme, le modèle d’interdisciplinarité réflexive proposé semble peu adapté à l’organisation des pratiques actuelles dans le domaine de la recherche sur le changement climatique. Ainsi, dans l’article 3, nous émettons le souhait que les scientifiques de projets interdisciplinaires et les chercheurs engagés dans l’Etude des Sciences et des Technologies (Science and Technology Studies, STS), qui disposent d’une expertise au niveau du fonctionnement de la science et de ses relations avec la société, poursuivent et développent les réflexions engagées. Une question essentielle se pose en effet aujourd’hui : comment structurer et adapter les recherches interdisciplinaires et réflexives sur le changement climatique à une interface science-politique confrontée à l’urgence, la complexité et l’incertitude des problèmes environnementaux globaux ?

Enfin, **l’article 4** envisage la question de la mobilisation des savoirs interdisciplinaires dans la prise de décision politique. Nous tentons de relier les perspectives offertes par la littérature STS sur l’interface science-politique, et les savoirs mis au jour par les scientifiques interdisciplinaires actifs à cette interface. Cet article identifie des divergences importantes entre ces deux communautés scientifiques, notamment au niveau des représentations sur le changement climatique. Tandis que les chercheurs en STS soulignent la nature intrinsèquement complexe, incertaine et incontrôlable du changement climatique, les scientifiques mettent en avant le fait que les incertitudes peuvent être réduites et limitées, et que la quantité grandissante de savoirs sur le sujet peut venir à bout de la complexité du climat.

Ces représentations diverses sous-tendent des perspectives divergentes sur la nature des actions et des interactions à l'interface science-politique pour le changement climatique. En effet, les scientifiques, pour leur part, optent plutôt pour un 'modèle déficitaire', selon lequel il s'agit 'd'éduquer' les acteurs sociaux et politiques afin qu'ils puissent prendre les décisions adéquates face aux questions concernant le changement climatique. Les chercheurs en STS, quant à eux, prônent des approches 'post-normales', pour lesquelles les savoirs sur le changement climatique sont co-construits par les scientifiques et les acteurs socio-politiques. Afin de définir des modalités pour que les savoirs interdisciplinaires puissent être mobilisés à l'interface science-politique, l'article 4 propose un dialogue réflexif entre les chercheurs en STS et les scientifiques. L'intention des partenaires, au cours de cet échange, étant de coopérer pour faire émerger un nouveau dessin de cette interface.

A travers les quatre articles rapidement décrits ci-dessus, cette thèse de doctorat tente de montrer que la réflexivité est une dynamique enrichissante, adaptée à la mise en œuvre de pratiques d'interdisciplinarité 'authentique' dans le domaine du changement climatique. En effet, le questionnement - personnel et collectif - des présupposés sociaux, ontologiques, épistémologiques et méthodologiques dans lequel elle engage les scientifiques, est propre à développer les attitudes de recherche coopérante, telles que l'ouverture, l'authenticité, la modestie, ou la reconnaissance.

Cependant, tout comme l'interdisciplinarité, la réflexivité est un processus d'apprentissage de long terme, qui requiert des efforts, du temps, de la patience et de la persévérance, surtout de la part de ceux qui ne sont pas familiers avec cette pratique. Compte-tenu de l'investissement demandé par la recherche interdisciplinaire et réflexive, et des exigences qu'elle requiert sur le long terme, l'organisation actuelle de la recherche en Europe, ancrée dans une logique gestionnaire et suivant des principes d'efficacité, de prestige, de concurrence et de hiérarchie, semble mal adaptée à ces pratiques de recherche.

C'est pourquoi l'une des pistes déployée par cette thèse de doctorat est celle d'un dialogue réciproque entre chercheurs en STS et scientifiques. Il apparaît en effet essentiel de repenser l'organisation actuelle de la recherche pour le changement climatique, ainsi que l'interface entre sciences du climat et sphères sociales, politiques et économiques. Une évolution qui prend en compte la complexité, les incertitudes et la pluralité des perspectives légitimes qui entourent la question du changement climatique.

List of publications

Paper 1: Blanchard, A., & Vanderlinden, J.-P. (2010). Dissipating the fuzziness around interdisciplinarity: The case of climate change research. *Surveys And Perspectives Integrating Environment and Society (SAPIENS)*, 3(1).

Paper 2: Blanchard, A., & Vanderlinden, J.-P. (forthcoming, 2011). Prerequisites to interdisciplinary research for climate change: lessons from a participatory action research process in Île-de-France. *International Journal of Sustainable Development (IJSD)*.

Paper 3: Blanchard, A. Overcoming the challenges of interdisciplinarity? A model of reflexive interdisciplinarity for climate change. (Under submission; modified from a previous version published in French as: Blanchard, A., & Vanderlinden, J.-P. (forthcoming, 2011). Interdisciplinarité et outils réflexifs : vers une approche globale des trames vertes urbaines. In P. Boudes & M. Colombert (Eds.), *Adaptation aux Changements Climatiques et Trames Vertes Urbaines*. Paris: Quae, collection Indisciplines)

Paper 4: Blanchard, A. Invitation to reflexive dialogue on the science-policy interface for climate change (Under submission)

Contents

Introduction

This PhD dissertation looks at how interdisciplinary research, more particularly in relation to climate change, emerges and develops; and how the resulting interdisciplinary knowledge is mobilised at the science-policy interface. It is hence not a PhD about climate change *per se*; rather, climate change constitutes the overarching context to the reflexive and critical[1] understanding of interdisciplinary dynamics within the broad scientific community.

This PhD follows five interrelated objectives:

1. First, it aims to explore why, in terms of contributions, interdisciplinarity has found particular popularity around the issue of climate change over the past 20 years[2].

2. Second, it aims at contributing to an increased understanding of interdisciplinarity, both theoretically and procedurally. Theoretically, the thesis endeavours to (a) define and frame it aside other research types, from disciplinarity to transdisciplinary approaches; (b) highlight its key constitutive characteristics or dimensions; and (c) provide insights into its origins and history[3]. Procedurally, it tries to better understand the mechanisms of interdisciplinarity in terms of

[1] In this Introduction, and more widely throughout the PhD dissertation, critical thinking is discussed in terms of the Frankfurt School. According to the 'critical theorists' of the Frankfurt School, a scientific theory should not only seek the understanding of the world, but should also help transform society by creating social and political conditions more conducive to human flourishing than the present ones (Adorno & Horkheimer, 1944).

[2] See discussion in Sections 1.2, 1.3 and 3.1.c of the Introduction

[3] See discussion in Paper 1 and Section 3.2.a of the Introduction

facilitators, limiting factors, challenges and ‘prerequisites’, in order to help actors involved in interdisciplinary initiatives to concretely implement it[4].

3. Third, it focusses on the concept of reflexivity and critically evaluates its specific contributions to the emergence and development of interdisciplinarity, and to the mobilisation of interdisciplinary knowledge at the science-policy interface[5].

4. Fourth, it proposes a model of reflexive interdisciplinarity for climate change, articulated around four reflexive tools: ‘inaugural contracts’, ‘harmonised presentations’, ‘summary tables’, and ‘writing pauses’[6].

5. Finally, the exploration of interdisciplinarity and reflexivity constitutes the basis for a critical questioning of the current practices and organisation of research for climate change; and its communication across the science-policy interface. To this degree, this research attempts to engage reflexive dialogue between scholars in Science and Technology Studies (STS), theorising on the role of science for climate change, and those scientists active in interdisciplinary projects and at the interface[7].

These five objectives reflect the two broad levels of motivations (further described in Part 1) that guide the PhD: first, a pragmatic, action-driven attempt to support actors involved in interdisciplinary initiatives to make sense of and concretely implement these dynamics, in a way that best fits their own issue; and second, an attempt to step back and critically question

[4] See discussion in Papers 2 and 3

[5] See discussion in Papers 2 and 3, and in Section 3.2 of the Introduction

[6] See discussion in Paper 3 and in Section 3.3 of the Introduction

[7] See discussion in Papers 3 and 4 and in Section 3.3 and 3.4 of the Introduction

the current science-policy models with regard to the complex global problem of climate change.

This Introduction, in order to link the four stand-alone papers and propose further discussions, is composed of three parts. Part 1 presents the overarching context of the PhD, against the backdrop of the 'wicked' issue of climate change, and presents the three main sets of reasons, or rationales, whose meeting constitute the departure point for this PhD research. Part 2 describes the two-level fieldwork and qualitative methods used in the PhD, and discusses the challenges and limits of this approach. Part 3 turns to address the four papers; presenting a discussion which at once distils the contributions and limits of each paper, and provides a thread of continuity between them; providing some overarching support to the structure of the thesis. Finally, in concluding, this Introduction asserts the need for further research, especially toward exploring the contributions of 'reflexive interdisciplinarity' to facilitate a broader dialogue beyond the boundaries of science; dialogue between scientists and other social, political and economic actors concerned by the issue of climate change.

1. From where has this PhD emerged? Overarching context and rationales

Climate change represents one of the major issues of our time. It challenges the whole of humanity to re-examine its relationship with the natural world, and consider the prospect that we may be changing the conditions for life within our only habitat; Earth.

Since the mid-19th century, scientific knowledge has been accumulated on Earth's warming atmosphere, with increasingly strong correlations made to human activities. However, while it has been the scientific community that has drawn our attention to the prospect of anthropocentric climate change, these scientific steps[8] have been as much a product of the social contexts of their time (Hulme, 2009). In this way, it was not until the 1960s and the gathering environmental movement spurred by influences such as Rachel Carson's book 'Silent Spring' (1962), that climate change came to assume a more alarming and urgent role in political, economic, scientific and social discourse. Rommetveit, Funtowicz and Strand (2010) thus argue that climate change presents a unique type of issue in that it is (i) truly global, encompassing all countries, and ominously unpredictable; (ii) cutting through all sectors of society; and thus (iii) concerns every facet of our lives as parents, community members, professionals and consumers.

Faced with such a pervasive issue as climate change, how should we respond? One important facet of humanity's response lies with the scientific community. As they first alerted us to climate change, so have we entrusted them with the important task of

[8] In fact these steps have been described as drastic changes, dislodging long-established perspectives on science as a gradual and incremental process of accumulation. In this way, these steps in the science are perhaps better described in terms of Kuhn's notions of 'scientific revolutions'.

‘understanding climate change’, to the degree that we can predict the future trajectory of our climate, and design our society accordingly. This global rallying of humanity’s scientific knowledge and expertise has found its most well-known and potent expression within the Intergovernmental Panel on Climate Change, which provides an institutional point of entry for scientists into the global debate constituting our collective decision-making. In this way we see the explicit role of the IPCC being to “provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts”[9], while simultaneously assuming a less comfortable role as a powerful political stakeholder. In this way, climate change has been a ‘call to arms’ to put scientific practice under the ‘magnifying glass’ for complex global issues, while also asking scientists to reflect in ‘the mirror’ on the role of their science within a high stakes political debate[10]. Beyond the IPCC, we can see internationally similar, though smaller, clusters of scientific initiatives researching climate change. Following the example of the IPCC, many of these initiatives take the form of cooperative projects, which bring together various disciplines and research organisations.

It is within the institutional context of scientific initiatives for climate change that this thesis locates itself. This research explores one particular scientific consortium studying climate change from within the region of Paris, in France. This research particularly looks at how this consortium gives effect to authentic interdisciplinary climate science, and what can be learned from an emphasis on attitudes of reflexivity.

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[9] See the IPCC’s online website: http://www.ipcc.ch/organization/organization.shtml; Accessed 25th September 2011.

[10] In his book, Hulme (2009) introduces the metaphor of climate change as a mirror and magnifying glass: “As a magnifier, climate change allows us to conduct examinations [...] of each of our human projects [...]. And as a mirror, climate change teaches us to attend more closely to what we really want to achieve for ourselves and humanity”.

This PhD results from the meeting of three sets of rationales: (1) normative assumptions on interdisciplinarity and climate change; (2) a theoretical positioning promoting reflexive and critical thinking; and (3) the institutional context of this PhD project. However, before describing these three rationales and the way they met, we will first concentrate on the overarching context of the PhD: that of climate change as a 'wicked problem', giving momentum to interdisciplinary research.

1.1. First element of context: climate change as a 'wicked problem'

The latter half of the 20th century has seen a changing representation of the interactions between the social and environmental spheres, led by advances in the fields of ecology, systems theory and chaos theory. Increasingly, interactions between society and the environment have been modelled as complex and adaptive systems, operating simultaneously at multiple scales (see Section 1.2. for deeper insights into these ontological evolutions). Since the 1980s, this has seen particular attention given to global environmental changes, including climate change. A number of authors across different disciplines have discussed the new typology of environmental issues that arise when we consider global change. Hence, global issues like climate change have been variously described, by those in planning and policy-analysis fields for instance, as 'wicked' (Rittel & Weber, 1973), 'unstructured' (Engels, 2005) or 'meta' (Cartwright, 1973) problems.

These labels, reflecting different ways of characterising complex issues, can be argued nonetheless to share three broad properties, distilled in the work of Funtowicz and Ravetz (1993): (i) a high degree of complexity within the ecological systems associated with the issue, leading to significant uncertainty (or indeed complete ignorance); (ii) a lack of consensus on the definition of the issue and its most appropriate solution, owing to a plurality of legitimate perspectives; and (iii) a decision-making process pressured by urgency and high stakes. When looking at the issue of climate change, we see that it exhibits all three of Funtowicz and Ravetz's characteristics.

a. Complexity and uncertainty

The complexity of climate change arises at several levels. First, climate change occurs in an open system, meaning that it is generated by a multiplicity of causal, often interrelated structures, mechanisms, processes or fields (Bhaskar, 2010). Indeed, feedback phenomenons and retroaction loops between the various components of the planet are frequent, and the percolation of the impacts through all the socio-economic sectors adds further 'emergent' complexity to the understanding of the mechanisms of climate change (Pittock, 2002).

Secondly, climate change is characterised as having both diverse and multi-scaled effects; impacting in an intertwined way at the local and global levels. To this extent, changes in climate dynamically impact the connected Earth systems with effects such as modifications in the atmospheric chemistry, deforestation, changes in the oceans' salinity, and soil loss and degradation (Bretherton, 1988; Steffen, Sanderson, & Tyson, 2004); changes that impact in turn on the climate. These various interconnected links imply that local perturbations can have global consequences (Cornell & Parker, 2010).

Finally, in link with the previous point, the existing climate models and observation tools face methodological limitations when attempting to understand the complexity of climate change. Significant uncertainties, extending to 'epistemological uncertainties'[11] (Funtowicz & Ravetz, 1990), remain regarding the long-term projections or the representation of complex phenomenons (Pethica, et al., 2010).

b. Plurality of legitimate perspectives

The plurality of legitimate perspectives around the issue of climate change can be argued to originate from three main sources. First, the plurality of perspectives appears to be triggered by the uncertainties around climate change, resulting from its intrinsic complexity and the impossibility of achieving a 'complete' knowledge of its mechanisms. This absence of 'objective' access to the issue translates into a lack of consensus on the definition of the issue and its most appropriate solutions, lending credibility to a plurality of perspectives.

The second source of this plurality stems from the first, and is based on Hulme's suggestion that climate change is not only a physical phenomenon, but can be defined as "an idea binding together the physical world and our cultural imagination" (2009). Accordingly, climate change finds a different echo in each individual, depending on one's personal, socio-cultural and historical identity which give voice to various representations of nature.

Third, plurality is based as well on the different epistemologies or ways of knowing within society, from science to local and traditional knowledge. Currently, science is the dominant provider of knowledge for decision-making around climate change; a significant example being the International Panel for Climate Change (IPCC). However, as will be argued in

[11] Epistemological uncertainties refer to the fact that we "don't know what we don't know". Even though this resembles to ignorance, Funtowicz and Ravetz prefer to talk about the border with ignorance rather than ignorance itself, because "the boundless sea of ignorance has shores which we can stand on and map". See as well the work of van der Sluijs (2006).
According to Edwards, "uncertainties exist not only because of quantifiable, reducible empirical and computational limits, but also because of unquantifiable, irreducible epistemological limits related to inductive reasoning and to the nature of model-based global science" (1999)

Section 1.2., the understanding of climate change across all its dimensions requires a perspective that goes beyond the scope of science alone. Indeed, action plans for climate change including the expertise and needs of the various actors concerned, and acting simultaneously within the environmental, social and economic spheres, over both short- and long-term perspectives, are more likely to be sustainable and efficient (Hulme, 2009).

c. High stakes and urgency

Climate change bears high environmental, social and economic stakes; strongly impacting on all facets of social and human organisations at both local and global scales: from regional agriculture to international trade, and from individual lifestyles to the substitution between energy sources (Costanza, 2010). As explained by Rommetveit, Funtowicz and Strand (2010), such changes in the livelihoods of social actors, as well as changes to the economy, represent very high stakes for three reasons: (i) as climate change concerns all countries, it seems to require world-wide communication and understanding; and (ii) as this issue impacts every sector of society, it poses great challenges of coordination of action across a number of sectors traditionally separated; and (iii) as it potentially concerns all the aspects of our daily lives, it demands integrated policies, involving social stakeholders together with decision-makers and scientists. However, the entrenched political interests in favour of retaining 'business as usual' have demonstrated their powerful influence, and in this way many nations have argued that it is not economically viable to adhere to global governance mechanisms like the Kyoto protocol.

Together with high stakes, climate change presents high urgency. Monbiot (2007) emphasises the need to take action before reaching a tipping point: "Curtailing climate change must become the project we put before all others. If we fail in this task, we fail in everything else". However, there is an important risk of disengagement and inaction with adopting an urgency-based communication on climate change, due to "a growing sense of urgency coupled with a lack of knowledge of what to do and a lack of institutions where the issues could be addressed" (Rommetveit, et al., 2010).

As a wicked problem[12], climate change poses questions of what is the most appropriate epistemology to mobilise knowledge in support of society's governance response, which constitutes the overarching context of this PhD. How does society come to 'know' multidimensional problems in order to devise and enact multidimensional responses? This is to what we now turn, by introducing interdisciplinarity as one possible epistemological access to climate change.

1.2. Second element of context: climate change legitimating interdisciplinarity

In the first half of the 20th century, climate scientists conceptualised climate as "something static, except at geological timescales" (Lamb, 1959). Climate was determined to fluctuate around a statistical equilibrium, according to self-maintaining feedback mechanisms. Similarly, any change in the climate was depicted as a linear, unidirectional and predictable progression. This ontological representation promoted the reductionist study of one or two

[12] Since the work of Funtowicz and Ravetz do not propose a name for problems such as climate change, I use in this dissertation the term of 'wicked' problems. Rittel and Weber's terminology is well known and seems to be the most relevant, as wicked problems are fundamentally similar to those referred to by Funtowicz and Ravetz; with relatively semantic differences. Instead of complexity, plurality and urgency, wicked problems are described according to (a) a difficulty to define and frame the issue; (b) uncertainties; and (c) solutions that rely on the collective judgement of a diversity of stakeholders.

variables in isolation, such as atmospheric carbon dioxide and temperature, as demonstrated through the pioneering work of Tyndall (1861, 1863) and later Callendar (1938, 1939) for example.

However, as noted in Section 1.1., with the increased awareness of complex global issues such as climate change, and parallel intellectual developments in ecology and systems thinking for example, the latter half of last century saw new ontological and epistemological representations emerge within natural sciences. Specifically, the world became understood as the relationships between diverse systems, of which the climate system presented only one component, necessitating a more holistic approach to understanding global systems (Capra, 1996). This spurred Manabe (1975) and others to take advantage of recent improvements in computing power to simultaneously model climate change as multiple interacting systems variables, while ecologists such as Odum (1993) proposed presenting the Earth as one bounded system labelled 'Spaceship Earth'. Similarly the climate, as for ecosystems for instance, was argued not to rest in any one state of equilibrium, but rather move between different states of equilibrium that are more or less stable, according to different sources of perturbation (May, 1972). Indeed, climate systems were regularly shown to exhibit significant non-linearity, meaning that even tiny perturbations can 'flip' systems into different states of stability, as depicted in ecology's 'adaptive cycle' (Holling, 1973). For example, the work of Broecker (1987) showed that the climate could change abruptly according to different thresholds.

Beyond this, climate change also called into question many of the ontological norms of climate scientists. In parallel with ecologists like May (1974), and chaos theorists like Lorenz (1963), climate change demonstrated the complex intricacy and unpredictability of interactions between non-linear systems. Drawing parallels with the work of Lorenz on weather systems, the metaphor of 'the butterfly effect' can be employed, whereby the slightest perturbation from the flap of a butterfly's wings could contribute to a hurricane on the other side of the world. At the same time, complexity science looked at how these interactions evolved and organised themselves into complex wholes, seeking to find the underlying simple roots that gave rise to complex behaviour, or indeed vice versa, how complex roots could give rise to simple behaviour (Waldrop, 1992). For atmospheric scientists, this was described in terms of 'emergent properties' and exemplified by Lorenz in terms of weather patterns, which were described as highly unpredictable in any exacting way. From these developments, in ecology for example (Francis, 2006), some scholars began to describe climate systems as 'complex adaptive systems'. As an outcome, climate scientists have at times been faced with an irreducibly complex and inherently unpredictable ontological representation of the natural world, with implications for the way they gain epistemic access to such a world, in particular towards interdisciplinary practices.

1.3. Rationale 1: Normative assumptions on the role of science for climate change

To sum up the ontological and epistemological evolutions mapped in Section 1.2., the paradigm of 'normal science'[13] (Kuhn, 1962) has constituted, since the Enlightenment, a dominant ideal for well informed decision-making (Allison & Hobbs, 2006; Funtowicz &

[13] More particularly, Kuhn described normal science as a fragmented disciplinary endeavour, wherein scientists progress their field of knowledge incrementally according to the norms and rules of their discipline. Scientific inquiries are exclusively reserved to the scientific community, motivated by curiosity and 'puzzle-solving', and in quest for 'perfect' knowledge. This type of science is rather non-transparent, with a highly formalised language that makes it impermeable to interactions with other forms of knowledge.

Strand, 2007; Ravetz, 1971). Normal (natural) science could be described as a venture of gaining universal knowledge by collecting it through highly specialised and disciplinary studies of precise questions, and by following a strict normative code. This thesis begins from a rationale that this epistemological approach alone is inadequate for supporting decisions on climate change, and therefore takes as its point of departure a growing body of literature endorsing 'sociological' traditions of mobilising knowledge.

Fuller (2007) has described sociological traditions challenging science-centric approaches over the past 40 years, with regard to global, complex and uncertain issues such as climate change, where no one perspective can have access to the totality of knowledge. In opposition to normal science, these approaches consider knowledge as socially derived, rather than an exercise in objectivity. It then ceases to give preference to any one group of stakeholders or their knowledge system; all forms of knowledge are extended a degree of legitimacy (Fuller, 2007). Rather than prescribing normative standards for how knowledge *ought* to be collected, sociological models seek to describe how knowledge *is* negotiated in political arenas, and explore the diversity of subjective knowledge perspectives (Jasanoff, 1995). Such approaches to generating knowledge and mobilising it in support of decision-making have found increasing attention in various fields addressing 'environmental governance'. These include discussions on deliberative democracy in political science (Dryzek, 2002), social network theory in sociology (Wellman, 1991), co-management in resource management and political ecology (Armitage, Berkes, & Doubleday, 2007), participatory planning within planning (Innes, 1999), and a discussion of alternative epistemological approaches within science and technology studies and the philosophy of science. This has seen the emergence of models of transdisciplinarity (Klein, 2000; Nicolescu, 2002), Mode 2 science (Gibbons, et al., 1994), and to post-normal science (Funtowicz & Ravetz, 1990; 1993).

These diverse models share four common reasons for justifying participatory knowledge construction and decision-making around wicked problems (Pahl-Wostl, 2002, 2005; Reid, Berkes, Wilbanks, & Capistrano, 2006):

1. Substantive reasons: given wicked problems cannot be entirely understood by science only, they appeal for the inclusion of different epistemological perspectives, in order to achieve a more exhaustive knowledge on the issue.

2. Normative reasons: by encouraging democratic participation for knowledge construction and decision-making around the issue, the outcomes of both processes will be legitimised.

3. Instrumental reasons: to address high-stakes politics, the participation of actors who have a stake in the issue supports the implementation of decisions into action.

4. Social learning: encouraging actors to learn about the issue, about other actors' values, and about the decision-making process allows issues to be solved.

More specifically, many STS authors (e.g., Funtowicz & Ravetz, (1990, 1993); Rommetveit et al., (2010); van der Sluijs, (1997)) argue that, as a wicked problem, climate change demands science that is: (1) *interdisciplinary*, in order to better understand and work within the complexity and uncertainties surrounding this issue; (2) *adaptive*, through the constant revision of theories as systems change; (3) *participatory*, to include the needs of the various social and political stakeholders, and elaborate solutions through various tools, on various agendas; and (4) *reflexive* about its objectives and the socio-economic and environmental consequences of its inquiries.

This PhD project focusses on 'interdisciplinary' science, according to substantive, normative, instrumental and learning rationales. It is important to emphasise, however, two main limits of interdisciplinarity for climate change, if it is not coupled to other mechanisms of knowledge creation, more participatory and extending outside the scientific community.

First, as discussed further by Paper 4, scientists working in interdisciplinary projects for climate change often remain in a tradition of 'normal science', which support beliefs of always 'perfectible' knowledge through the combination of various disciplinary approaches; and thus diminishes the role and legitimacy of non-science in decision-making processes. The preference for sound scientific knowledge rather than dialogue across knowledge systems and experiences can be explained by the essence of the scientists professional role (i.e., modelling reality, reducing uncertainties and predicting the future), as well as the way science as an institution works, according to standards of truth and objectivity. However, dialogue and participation are argued by many to be key for developing *relevant*, *sustainable*, *multi-dimensional* answers to climate change, including the needs of the various actors, and find expression through various tools, over various agendas (Hulme, 2009, 2011; Rommetveit, et al., 2010). This implies that interdisciplinary initiatives should be made accessible to the scrutiny of relevant non-scientific actors, to embed this science in its social context, and thus render it more legitimate, credible and salient to society (Fabricus, Scholes, & Cundill, 2006).

Second, and following the first point, as interdisciplinary initiatives largely remain the domain of scientists engaged in them, this may present a self-reinforcing loop; many of these projects are destined to repeat old mistakes. There is rarely an impetus to engage in a reflexive challenging of current ‘paradigms’, neither in the generation of interdisciplinary science, or its communication across a science-policy interface. To borrow from Kuhn, these are not conditions for ‘scientific revolutions’. As is argued in Papers 3 and 4, the initiation of dialogue between scientists engaged in interdisciplinarity for climate change, and STS scholars, could encourage reflection on current models of interdisciplinary science. Going beyond this dialogue, opening interdisciplinary knowledge to the scrutiny of actors who have a stake in climate change, seems fundamental in order to ensure that the knowledge created is sustainable and relevant.

1.4. Rationale 2: Positioning within the wider scholarship: tying reflexivity to interdisciplinarity

The PhD’s theoretical positioning concentrates on the links between reflexivity and interdisciplinarity. This particular focus demonstrates the originality of this PhD, as few studies of the STS and social science literature have concentrated on the relations between reflexivity and interdisciplinarity.

This theoretical positioning finds its early origins in my educational background, which has allowed me to navigate between what C.P. Snow calls ‘the two cultures’ (1998), from natural sciences to social and human sciences. Beyond realising their ontological, epistemological and methodological differences, their different attitudes towards knowledge, and their different perception of the role of science, this experience of navigating between natural and social and human sciences has highlighted for me the benefits of cooperation between them, in dealing with the complex issues of a changing world; as much in substantive terms as in terms of a collaborative reflexive questioning of their respective models of science, society and policy.

However, the experience across these two cultures led me to realise their lack of interactions. Envisioning the potential contributions of interdisciplinarity, I was interested in exploring, through this PhD project, the reasons for this lack of cooperation, beyond the material, technical and institutional factors, such as time and money, which often lead the discussion in the literature (see, e.g., Brewer, 1999; Jakobsen, Hels, & McLaughlin, 2004). More specifically, authors like Snow (1998) point at more upstreamed reasons to this weak dialogue between natural, 'hard', and social and human sciences; first, a lack of *authentic* interest in the other scientific community; and second, a lack of *reflexive* scrutiny of the 'home' discipline.

Among the few studies which explored reflexivity in link to interdisciplinarity, three inspired the starting point of this PhD. First, the action research project of Romm (1998), concerned with the relationship of women and law in Southern Africa, suggested that interdisciplinary research is distinguished by the seriousness of researchers' reflexive endeavours to reexamine their initial points of focus through the meeting with other perspectives. Focussing on the issue-based nature of interdisciplinary initiatives, the author asserts that is it reflexivity itself that enables researchers to ‘‘[take] on board ideas [and] interpretations exceeding the boundary of some source discipline’’. Keeping with this theme, Wickson, Carew and Russell (2006) point at the importance of 'reflection' for transdisciplinary research, as a way for researchers within such initiatives to validate their results. Indeed, because they are engaged in the issue they are investigating, issues of 'objectivity' are posed. 'Transdisciplinary' researchers should hence ‘‘reflect on how their own frames of reference, values, beliefs [and] assumptions [shape] the conceptualisation of the problem, as well as the development of the method of investigation and the solution''. This 'reflection', which relates to the definition of reflexivity of Bourdieu (2001) (see hereunder), includes as well, through the meeting of the various knowledge systems involved, a scrutiny of their underlying values and assumptions. Finally, Klein (2004), through linking the ideas of interdisciplinarity and complexity, invites to a reflexive exploration of the nature of knowledge, the structure of the university, and the dialogue between science and humanities. This reflexive scrutiny of the role, shape and organisation of science in a context of complexity constitutes an important aspect of this PhD (see Paper 4).

This PhD endorses the same point of departure as Romm, Wickson et al., and Klein; whereby reflexivity sets the ground to the recognition of a plurality of legitimate perspectives, and their inclusion to the process of knowledge creation. However, in opposition to the first two authors, reflexivity in this PhD is less a matter of 'democratising' the scrutiny around scientific practices, thus reinforcing its 'social relevance' and 'validity' (we could then talk about transdisciplinarity rather than interdisciplinarity); rather, reflexivity has become the focus for bridging the different worlds of social and natural sciences, in order to launch critical reflections on what it means to be interdisciplinary in the context of climate change. Moreover, counter to these three studies, we emphasise the relationship between reflexivity and 'authenticity' as two faces of the same coin, forming the basis to interdisciplinary cooperations.

On the one side of the coin, we start from Bourdieu's definition (2001; 1992) of reflexivity as a self-examination undertaken by the scientist, translating the capacity to recognise and make explicit his/her experiences, presuppositions, motivations, preferences and interests, and their impacts on scientific research (see Section 3.2 for a fuller description of reflexivity in the context of this PhD). At the disciplinary level, the scientist should be able to reflect on the underlying principles and purposes of his/her discipline in order to better understand his/her relationship to other researchers or other disciplines. Bourdieu's work is in parallel with that of Worster (1979), who proposed reflecting on the history of a discipline in order to understand its current ontological, epistemological and methodological access to the world, and challenge the reflection and action schemes inherent to that discipline. Achieving this personal knowledge facilitates interactions beyond disciplinary boundaries by nurturing attitudes of authenticity. Being authentic is taking the risk of revealing one's 'true colours' in the dialogue with others; it is daring to be oneself, and acknowledge one's own imperfections and weaknesses (Jollivet-Blanchard & Blanchard, 2004).

On the other side of the coin, attitudes of authenticity reinforce in turn reflexivity. Indeed, beyond this honesty with oneself and others, authenticity implies being able to scrutinise and challenge the others' and one's own perspective and assumptions: "I form a team with you, not if you are complaisant with me, […] but if your presence encourages me to be stronger, and invites me to give the best of myself, the most rigorous, the deepest, and the most authentic possible"[14] (Meirieu, 1996). In this way, authenticity is a fundamental dimension of reflexivity, and thus of interdisciplinarity: (1) it encourages a departure from neutral and complaisant interactions, for challenging, questioning and respectful ones; and (2) it allows for a diversity in the dialogue, as it is a way to share one's own motivations, practices, or goals. Thus, authentic interactions invite new questions and new perspectives.

[14] Translated from French to English by the author. Original quote: "Je forme une équipe avec toi, non pas si tu excuses mes faiblesses, […] mais si ton regard m'invite à être plus fort et ta présence à donner le meilleur de moi-même, le plus rigoureux, le plus approfondi, le plus authentique possible." (p.172)

The above-sited literature and my university background form the frame of the theoretical positioning of this PhD; however, reflexivity was introduced into the PhD according to a participatory action research with scientists involved in interdisciplinary initiatives (see Section 3.2 for the definition of reflexivity in the context of this PhD). It is to this institutional setting that we now turn.

1.5. Rationale 3: Institutional context of the PhD project

This three-year PhD project has been funded by the Scientific Consortium for Climate, Environment and Society (GIS CES), via the University of Versailles Saint-Quentin-en-Yvelines (UVSQ). The GIS CES was set up in March 2007, and is part of the '2004-2012 climate plan' of the French government; a plan which provides guidance to respect the commitments given by France to the Kyoto Protocol in 1997. This document defines as well ''national actions for preventing climate change'' (Borloo, 2004).

The GIS CES received 8 million Euros over a period of five years (2007 - 2012), provided by six founding members: the French National Centre for Scientific Research (CNRS), the French Atomic Energy Commissariat (CEA), the French Environment and Energy Management Agency (ADEME), and three Parisian universities, including the UVSQ. Parallel support was also given by the French Ministry of Higher Education and Research, and the Ministry of Ecology and Sustainable Development.

With such resources, the GIS CES has the objective of supporting, facilitating and coordinating interdisciplinary research for climate change between 16 laboratories in the region of Paris, working mainly within the fields of climatology, hydrology, ecology, health, economics (both environmental and ecological) and the humanities and social sciences. These interdisciplinary projects aim to study the impacts of climate change on energy policies and socio-economic development, vulnerable regions, ecosystems, use of soils and water resources, and health.

However, after one year trying to implement such interdisciplinary dynamics, the GIS CES scientists realised, with the facilitation of STS (Science and Technology Studies) researcher and GIS CES partner Jean-Paul Vanderlinden, that this was not a matter of good-will alone. Not only was it a long and expensive process, the scientists were also confronted with a less visible and material barrier; that of knowing how to cooperate beyond disciplinary boundaries, and giving effect to projects with authentically interdisciplinary outputs; i.e., innovative, integrated scientific results and changes in research attitudes towards more cooperation, openness and flexibility.

After a long process of debates and discussions over the utility of *guidance* while implementing interdisciplinary projects, the GIS CES funded this PhD project in October 2008 under the name: 'Research and Animation: Mobilisation and Structure of Interdisciplinary Knowledge, and Interface between Science and Society' (the RAMONS project[15]). RAMONS had the objective of "concretely helping the GIS CES scientists to give effect to true interdisciplinary cooperations around climate change". Accordingly, this PhD project started from a strong action-oriented impetus; with the mission of understanding and giving effect to interdisciplinarity, through practical tools, methods and guidelines. As explained in Part 2, these pragmatic expectations made it challenging, in the PhD, to move towards a more theoretical and critical endeavour.

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[15] The acronym RAMONS stands for the French project title: 'Recherche et Animation: MObilisatioN des Savoirs, structuration interdisciplinaire des connaissances, et interface entre science, société et politique'.

2. Fieldwork and methodology

The objective of Part 2 is not to exhaustively delineate the fieldwork and qualitative methods of data collection and analysis, as these are described across the four papers. Rather, this discussion takes the opportunity to (i) explain the choices of case studies and research methods; (ii) discuss the limits inherent to such choices; and (iii) explore the transition, in the PhD, from a rather pragmatic to a more theoretical and critical perspective.

2.1. Fieldwork: two levels of exploration

This PhD dissertation is based on a two-year participatory action research from 2008 to 2010, between the climate-related scientists[16] of the GIS CES and the two action researchers (Jean-Paul Vanderlinden and the author), both scholars in STS. The research was undertaken at two different levels: a 'global' level first, attempting to apprehend the whole GIS CES structure; followed by a 'local' level, focussing on two specific GIS CES interdisciplinary projects. These two levels are reflected in the four papers constituting this PhD: Paper 1 and Paper 2 present the 'global' level results; while Paper 3 and Paper 4 display the results form the 'local' level.

a. The 'global' GIS CES level

The first level concerns the broad GIS CES structure. Following the GIS CES incentive for pragmatism and action, the participatory action research first set out to understand how the

[16] In this thesis, when we talk about 'climate-related scientists', we do not only refer to the natural and 'hard' scientists concerned with the study of climate change (i.e.: meteorologists, ecologists, hydrologists, geologists, physicists, mathematicians, etc.); we also refer to the scientists from social and human sciences, economics, health and history, involved in research on climate change.

GIS CES structure was working, and what kind of experiences, representations, motivations, interests and practices of interdisciplinarity were coexisting among its various members. To this aim, the action researchers interviewed both project leaders and members of the GIS CES 'steering committee'; in charge of evaluating the "degree of interdisciplinarity, relevance, feasibility, and level of international networking" inherent to the project proposals, and fund those which were respecting these criterions[17]. In order to grasp this global picture of the GIS CES, the interviewees were invited from across a diversity of disciplines, ranging from climatology to biology, history, economics and health.

The diverse perspectives collected were then shared with the GIS CES scientists, in order to support the collective drawing of a 'roadmap' for interdisciplinarity, and thus help struggling projects with concrete guidelines and tools. This 'global' inquiry allowed for: (i) the linking of experiences, representations, and practices of interdisciplinarity; (ii) a better framing and understanding of the concept of interdisciplinarity; (iii) the exploration of concrete

[17] One of the obstacles for giving effect to interdisciplinarity within the GIS CES lay in the criterions themselves. The 'degree of interdisciplinarity' was merely judged by the number of disciplines present in the project (an act of box-ticking), but not by the methods proposed for cooperating across disciplinary boundaries; leading most of the projects to be multidisciplinary (see Paper 1). Furthermore, the 'relevance' and 'feasibility' criterions remained vague (were these criterions to be framed socially? Politically? Economically? Scientifically?), without indications of means provided by the GIS CES steering committee. Finally, the attempt at 'international networking' served to add complexity to an already uncertain process: implementing interdisciplinarity among the GIS CES laboratories was at that time an exploratory process and great challenge, requiring time and energy from the GIS CES scientists. This research argues that while international connections may be beneficial to the GIS CES's prestige and legibility; it was adding complexity and forcing interdisciplinary interactions in ways that were not necessarily the most relevant.
For instance, the scientists of the HUMBOLDT project (see Paper 3) that participated in our participatory action research, spent a significant amount of time on deciding whether they would interact with Latin American laboratories; before finally realising that "the methodological questions and objectives within HUMBOLDT are still not clear"; and that major scale issues (i.e., "reaching a 1 km scale, is a fantasy. It is unrealistic") and language issues ("You are using the word 'statistical downscaling' for something that is, to me, interpolation") still remain. (Quotes from the participants to the second focus group with HUMBOLDT, May 2010).

facilitators and barriers to interdisciplinarity; and (iv) the emergence of the key concept of reflexivity, as a 'prerequisite to interdisciplinarity' collectively identified by the GIS CES.

b. The 'local' GIS CES level

The 'local' level of the participatory action research focussed on two GIS CES projects[18], presented in Papers 3 and 4. Building upon the 'global' GIS CES experience, the 'local' inquiry focussed specifically on exploring the contributions of reflexivity to the implementation of interdisciplinarity, by testing reflexive tools structured around a model of 'reflexive interdisciplinarity', presented in Paper 3. This 'local' inquiry also instigated a critical discussion on the ways interdisciplinary knowledge can be mobilised at the science-policy interface for climate change, with these results and reflections presented in Paper 4.

The 'local' inquiry, in opposition to the 'global' one, was less steered by the GIS CES' imperative for concrete actions and results. Indeed, the physical distance created between the GIS CES and the author during the third year of PhD research in Bergen, emphasised that the role of a researcher is not merely to 'fix' a local problem. This could be considered the role of 'consultancy'. Rather, the researcher should be in a critical interaction with the topic of study. This shift to a more critical perspective is translated in Papers 3 and 4 by the emphasis put on the need for reciprocal dialogue between climate-related scientists[19] active in interdisciplinary projects, and STS scholars, who have expertise in the study of science and its relations to society. This dialogue is argued to bear fundamental contributions to the

[18] The HUMBOLDT project: Human Impacts on Biodiversity, Ocean Environment and Climate in the Anthropocene, funded by the GIS, for the period 2009 - 2012; and the CCTV project: Climate Change and Urban Greenways, funded by the GIS, for the period 2009 - 2010.

[19] See Footnote 16.

critical discussion of what it means to be interdisciplinary in a context of climate change, and to the collective rethinking of the science-policy interface for this issue.

c. Limits and challenges of this two-level fieldwork

The results arising from this two-level fieldwork face three main limits. The first limit could be argued to be the proximity of this PhD project with its funding institution, the GIS CES. Indeed, funded by this structure according to pragmatic expectations, the PhD initially adopted a practical orientation. This orientation facilitated the implementation and conduct of the participatory action research; where Papers 1 and 2 constitute the first steps of a creation of 'useful' and action-oriented theory on the basis of the GIS CES fieldwork[20]. While this more 'grounded' approach has its advantages, as a piece of PhD research, this thesis needed to shift to also take a more critical perspective, to make contributions to the scholarship.

Second, the scope of the inquiry, in terms of: (i) the number of participants, (ii) the number of interviews and focus groups, (iii) the number of iterations, and (iv) the length of the participatory action research, does not achieve a representative picture of the practices and challenges of interdisciplinarity for climate change, nor of the means that can be deployed in face of such challenges[21]. The results are relatively specific to the GIS CES context and to

[20] This method can be put in parallel with 'grounded theory'. This inductive approach aims at generating new theories in social sciences. The inquiry starts from practice, and the analysis moves along a constant adjustment to what is happening in practice. This implies of a researcher to temporarily ignore the existing theoretical frameworks, in order to discover new understandings of a particular phenomena, and to be open and sensitive to the emergence of new elements of theory suggested by the practical experience. Through grounded theory, the researcher is supposed to avoid the mere verification of existing theories (Glaser, 2002a, 2002b, 2004; Glaser & Strauss, 1967; Powell & Single, 1996; Strauss & Corbin, 1990).

[21] 15 interviews were run for the 'global' inquiry, and for the 'local' research, two sets of respectively 9 and 6 interviews, accompanied with two focus groups of 6 and 7 participants for one project; and for the other project: 22 participants to the launch meeting.

the French organisation of research. However, representativity was not the objective of this research. Rather, through the two-level inquiry, the aim was to understand the context-based representations and practices of interdisciplinarity within the GIS CES, from which we could derive deeper reflections and perspectives regarding the implementation of 'reflexive interdisciplinarity' for climate change, and the mobilisation of interdisciplinary knowledge for climate policies.

Third, the GIS CES scientists involved in the two-level fieldwork were volunteers. We can thus assume that they were curious, open and motivated; attitudes that seem to facilitate interdisciplinarity (Jakobsen, Hels, & J. McLaughlin, 2004). In this way, we could argue that the model of reflexive interdisciplinarity proposed in Paper 3 might be less accessible in reality. Nevertheless, even if the scientists were willing to participate in the participatory action research, and test the reflexive tools, they were often found to oscillate between a feeling of duty, and weariness towards a "lengthy process that [was] keeping [them] away from [their] discipline": "We are funding the RAMONS project to be psychoanalysed. This is great. But the scientific substance of our project is not a matter of RAMONS". It was therefore challenging to organise a coherent participatory action research set up in continuity, and the proposed model of reflexive interdisciplinarity takes into account these limits inherent to working in group: different interests, agendas, and motivations, together with conflicting relationships characterised by asymmetry and dependence.

2.2. Qualitative methodology: participatory action research

a. Definition

The two-level inquiry followed the method of participatory action research, which structured interactions with the GIS CES scientists throughout two years, along a cycle of individual and collective reflections and actions. This participatory action research is described in Paper 2 (for the 'global' level), and Paper 3 and 4 (for the 'local' level), but in order to contextualise the discussion of the contributions and limits of this approach, we here turn to the literature.

Participatory action research, initially developed by the American social psychologist Kurt Lewin (1946, 1947) in the 1940s, is a research inquiry which invites action researchers and the actors of the fieldwork to closely cooperate along iterative cycles of action and reflection (see Figure 1), where theory and practice mutually nurture each other (Kemmis, 1980; Susman & Evered, 1978). Action researchers and actors are encouraged to *cooperatively*: (i) define and frame their issue and research questions; (ii) choose their epistemological and methodological frameworks, characterised by a particular set of actors, values and resources; and (iii) reflexively assess the 'desirability' and 'sustainability' of their objectives and actions implemented (Kemmis, 2001; Reason & Bradbury, 2006).

This implies the constant adjustment of theory to practice, whereby actors cooperatively modify their theory and refine their actions to make them better fit to their objectives (Greenwood & Levin, 1998; Masters, 1995).

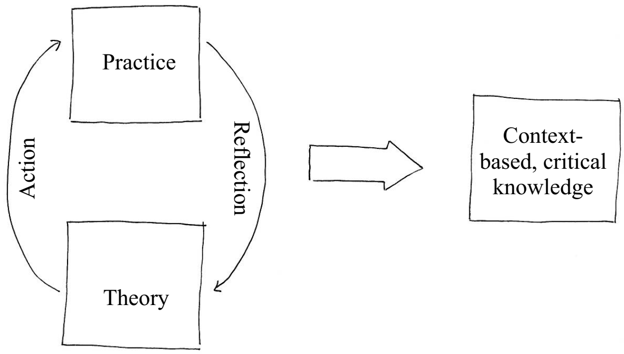

Figure 1: Synthetic diagram of participatory action research: theory and practice nurture each other along iterative and cooperative cycles of action and reflection

This long-term, context-based, cooperative, adaptive and reflexive process results in a critical knowledge construction which allows group of actors to cooperate within the context of uncertainties and complexity, by achieving incremental changes of the current institutions (Brydon-Miller, Greenwood, & Maguire, 2003; Hugon & Seibel, 1988; Stringer, 2007a, 2007b).

b. Contributions

The STS researchers chose to work with the GIS CES scientists according to a method of participatory action research for three reasons. First, as the time-consuming nature of interdisciplinarity was an important source of concern for the GIS CES scientists, participatory action research helped them to better come to accept the idea of 'giving up' some time. Indeed, interdisciplinarity is not, as many at first imagined, a means for enhancing efficiency through the distribution of tasks across members of a group. It is in fact a longer and less linear process than individual work. Therefore, by fostering a meta-reflection on the process and ends of interdisciplinarity, and developing an awareness of its contributions in terms of innovative results and personal enrichment, participatory action research helped the GIS CES scientists avoid a quick step back to individual research, which appeared temptingly more efficient at a first glance. The perspective of personal and scientific developments outweighed, or at least justified, the time spent on interdisciplinarity.

Second, participatory action research has encouraged the GIS CES scientists and the STS researchers to structure, at the early stages, our objectives according to a long-term agenda. A clear, but flexible agenda, drawn on a participatory basis, allowing space for adaptation to surprises met on the way, was a good solution to better navigate in complexity, avoid weariness and foster confidence. It allowed us to follow a coherent route, that made sense and satisfied the participants, without being disillusioned regarding the ends of the process. Moreover, it allowed us to easily come back to earlier steps of the process when tools needed to be rethought, or another route to be taken.

Third, as participatory action research is established in continuity, it prepared the ground for authentic interdisciplinarity. Indeed, the long-term commitment that an interdisciplinary project demands encouraged respect and authenticity among participants, through a better knowledge of the other scientists and disciplines. It also saw an increase in the ‘responsibility’ felt by scientists toward the project, and increased coherence and cohesion; factors that we found were supporting interdisciplinarity.

c. Limits

The participatory action research and its underlying reflexivity on the process, met three main limits. First, a methodological critique could be that the research method was ‘imposed’ on the GIS CES scientists, with their input limited to technical matters of implementation rather that any discussions of the overarching assumptions that justified the process (Johnson & Duberley, 2003). The question remains whether the GIS CES scientists should have been more involved in the methodological choices, with two relevant considerations. First, the initial steps of our participatory action research, that of agreeing upon a common definition of interdisciplinarity, and its means of implementation through reflexive tools, had already triggered some weariness from the scientists, not accustomed to such activities. Involving them more in the methodological choices might have resulted in an increased disengagement on their side. Second, as action researchers 'employed' by the GIS CES, it was part of their role to come up with approaches and tools suited to the GIS CES context.

A second limit refers to the organisation of research into short-term projects. The short-term nature of this PhD and a lack of time on the scientists' side, under pressure for efficiency in their own discipline, meant that our participatory action research process did not allow for adequate iterations. As continuity and coherence give rise to authenticity and a greater level of involvement and concern, the research would have benefited from more frequent meetings in order to reinforce the cohesion. There was a sense that, at each iteration, the group had to come back to the previous steps, including the definition of interdisciplinarity. This overarching issue of the dominant institutions for the organisation of research poorly adjusted to interdisciplinary and reflexive science, is more widely discussed in Paper 3, as well as in Section 3.3 of this Introduction.

Third, as authors such as Finlay (2002) argue, preoccupations with participation can divert attention away from other, possibly more pertinent issues. To this degree, this PhD research was not to be an exercise in participation, for participation's sake. Rather, there was required a conscious return to objectives of scientific outputs and learning. In this PhD, outputs were expected in terms of the achievement of results such as successful interdisciplinary projects to the GIS CES standards. Perhaps more significantly, the participatory action-research was a learning process in itself, whereby GIS CES scientists and STS action researchers together experienced the challenges of interdisciplinary cooperation, developed strategies to work with them, and arrived at context-based knowledge around them.

In conclusion, the methodological choices made for this PhD research face limits of scope and are relatively context-based; rendering difficult the direct derivation of recommendations for other interdisciplinary settings. However, it is the practice-embedded nature of the participatory action research itself that has triggered, particularly in Papers 3 and 4, more global reflections and critiques of the current organisation of scientific research, of the shape of the science-policy interface for climate change, and of the role of science for climate change.

3. Presentation of the papers and discussion

The PhD dissertation follows a structure in papers. This structure according to independent, stand-alone papers is interesting in that it shows the academic evolutions throughout the PhD research, especially in terms of (i) the definitions of interdisciplinarity and reflexivity, which became more precise and contextualised; (ii) perspectives regarding interdisciplinarity for climate change; and (iii) research attitudes, from a pragmatic endeavour to more critical and theorised attempts. These evolutions in the research also reflect the evolutions of the researcher.

On the other hand, a structure according to papers translates into less continuity and harmony than a monograph. Indeed, the vocabulary is not harmonised across the PhD, as the four papers have been written and published independently from each other; rendering the understanding of the concepts evoked in this dissertation less straightforward. Beyond vocabulary, this PhD structure also results in a more disjunct presentation of ideas; from Paper 1 to Paper 4, the perspectives on interdisciplinarity for climate change have evolved from an unquestioned acceptance of its 'desirability', to the critical scrutiny of its contributions in a complex and uncertain world. These changing ideas can contribute to a lack of coherence throughout the PhD.

Therefore, Part 3 provides a thread of continuity to the PhD, by explaining and adjusting the evolutions in terms of vocabulary, definitions, and points of view, by providing complementary discussions on the contributions and limits of each paper, and by situating them within broader questions and debates.

3.1. Paper 1: An attempt to 'dissipate the fuzziness around interdisciplinarity'

On the basis of the 'global' inquiry within the GIS CES, Paper 1 attempts to respond to a practical objective, that of 'dissipating the complexity around interdisciplinarity'. The underlying intention is to assist researchers and practitioners in the construction and development of interdisciplinary projects by providing a clear and comprehensive 'map' of the concept and suggestions for its practical implementation.

To this aim, the paper proposes a definition of interdisciplinarity in three parts. First, interdisciplinarity is defined in relation to three other research dynamics based on interactions between disciplines: pluridisciplinarity, multidisciplinarity and transdisciplinarity. This is to avoid confounding these research dynamics, which are often found to be used interchangeably in the literature and among practitioners. Second, Paper 1 gives insights into the origins and historical development of interdisciplinarity, as a basis for the exploration of the objectives and means of interdisciplinarity. And third, the key dimensions of interdisciplinarity, reflexivity and authenticity (under the label of 'confidence'), are discussed, as well as their intertwined relationship.

However, because of the GIS CES expectation for action and the short format and theory-orientation of the journal[22] in which Paper 1 was published, three aspects deserve complementary discussions.

[22] Online, peer-reviewed journal SAPIENS: Surveys And Perspectives Integrating ENvironment and Society. SAPIENS aims at "redefining the state of the art of the literature" by publishing "critical analysis and evidence-based opinions".

a. Tone and structure

The quite strong normative tone of Paper 1, as well as its carefully divided and numerated structure[23], are indicative of the difficulties encountered in making sense of a heavy literature, and finding a balance between oversimplification and the objective of 'being useful'.

Indeed, guided by pragmatic objectives, the complexity and interconnectedness within the literature needed to be simplified, in order to provide a practical 'map' for practitioners and researchers. However, in reality, the origins of interdisciplinarity influence its definition, which in turn influence the set of objectives it may fulfil. Moreover, 'confidence' and reflexivity are qualified in Paper 1 as ‘‘two essential values’’. However, these attitudes (which the author would not designate as values now) are situated at different levels, and come along with other attitudes, such as recognition and respect, which foster confidence and authenticity; and hence constitute cornerstones of reflexivity and interdisciplinarity. This will not be extended on more here, as Paper 3 displays these interconnections in terms of challenges to interdisciplinarity.

b. A changing perspective on horizontality

The definition of interdisciplinarity drawn in Paper 1 displays important features present throughout the PhD: cooperation, reflexivity, complementarity, recognition, and horizontality. However, the way horizontality is used in Paper 1 contradicts with Paper 3, where we claim that one challenge of interdisciplinarity is to accept to work in an

[23] The headings of Paper 1 are: 1. Introduction: Four complex features of interdisciplinarity; 2. Definition: Four levels of interaction; 3. Origins: Three main underlying purposes 4. Objectives: Two poles, three types; 5. Means: two essential values; 6. One concluding lesson: reflexivity

asymmetrical setting, and acknowledge that the actors involved in a same project do not have the same roles, contributions, priorities, and rhythms.

Hence, horizontality is less about an ‘equal’ level of participation and investment among the actors of an interdisciplinary project; rather, it is the recognition, within asymmetrical relationships, that each actor is in a position of authority, and that he/she can exercise this authority according to his/her own conscience and personal history (Jollivet-Blanchard & Blanchard, 2004). This idea of horizontality is as well found in the work of Héber-Suffrin (1998): ‘‘It is because we are equal and different, and because we are creative *together*, that a guarantee is established that a space of domination and submission will not be recreated’’[24].

c. ‘Extended’ interdisciplinarity encouraged by climate change

In the section on the origins of interdisciplinarity in Paper 1, we did not address the extend to which climate change has contributed to the emergence of interdisciplinarity, and more particularly of ‘extended interdisciplinary research’, binding together climate sciences with health sciences, economics, and social and human sciences. This type of interdisciplinarity, however, is relevant to the context of this PhD. This is expanded on here.

If climate sciences as a distinct field of enquiry are only about 50 years old, they have been built on interdisciplinary foundations reaching back to the 18th century, with meteorology and oceanography establishing bridges to understand Nature (Cornell, 2010). However, the shift of climate sciences towards a more integrated and issue-based orientation is growing, as

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[24] Translated from French to English by the author. Original quote: ‘‘C’est parce que nous sommes égaux et différents, que nous sommes *ensemble* créatifs, qu’est instaurée une garantie qu’un espace de domination et de soumission ne sera pas recréé.’’

shown by the social and political expectations towards comprehensive studies on climate change and its various impacts on society. This shift implies a reciprocal dialogue between natural and social sciences.

According to the literature, climate change appeals for this reciprocal dialogue, or extended interdisciplinarity, for three main reasons. First, while other fields of study may be characterised by disciplines, climate change is not (Shove & Simmons, 1997). The apprehension of this complex issue in all its dimensions requires approaches beyond the scope of a single discipline, and, going further, beyond the scope of the climate-related sciences. More particularly, reciprocal dialogue between natural and social sciences[25] may support an increased understanding and critical scrutiny of the socio-economic and political context in which climate change is created and experiences; and thus guide reflexive questionings and rethinking of our current social models (O'Brien, St. Clair, & Kristoffersen, 2010).

Second, as emphasised by Reid and colleagues (2006), as one way to improve decisions is to insure that the best knowledge concerning climate change and the potential solutions is available to fuel deliberation, knowledge derived from extended interdisciplinarity appears to be a relevant support for decision-making processes. Though better knowledge does not guarantee better choices will be made, it does provide a sound and rational basis for making better decisions and for holding decision-makers accountable, and leads to an extended participation in the debates at the science-policy interface for climate change (Jansen, 2007). Importantly though, interdisciplinarity can not claim to provide prefect knowledge; it can

[25] This idea of reciprocal and authentic dialogue between STS or social sciences and climate-related sciences is further developed in Papers 3 and 4.

indeed not dissipate all the uncertainties surrounding the facts and future projections of climate change, and is limited to a knowledge construction within the scientific sphere.

Third, as a result from the previous point, as extended interdisciplinarity supports a wider participation at the science-policy interface for climate change, it thus invites stakeholders concerned by this issue to be creative, and go beyond technological and managerial responses that focus on 'local' anomalies, but not on the sources of the problem (O'Brien, et al., 2010).

3.2. Paper 2: Linking interdisciplinarity and reflexivity through four 'prerequisites'

Paper 2 follows the idea triggered in Paper 1, according to which ''interdisciplinarity and reflexivity are [...] in an intertwined, evolving relationship'', with mutually reinforcing contributions to their respective implementation. More particularly, Paper 2 builds upon the 'global' inquiry within the GIS CES, which revealed failures in the development of some of their interdisciplinary projects. The focused study of these projects and of the scientists that participated in them revealed major divergences between these actors, regarding the definition of interdisciplinarity, their personal interests, motivations and expectations. These diverse interpretations remained implicit and unchallenged, subsequently leading to misunderstandings on the objectives and means of the project. Paper 2 therefore proposes four 'reflexive prerequisites'[26] providing an opportunity for actors of a same interdisciplinary project to make the above-cited features explicit during the construction phase of their project.

While Paper 2 is tightly linked to Paper 1, it exhibits important differences in the vocabulary and definitions of reflexivity and interdisciplinarity, which are seen to change further in Papers 3 and 4. These changes reflect how the interactions with the GIS CES scientists along the participatory action research have shaped the action researchers' perspectives both on reflexivity for interdisciplinarity, and interdisciplinarity for climate change. In this regard, this section provides adjustments and complementary discussion.

a. Adjustments on the definition of interdisciplinarity

The changes in the definition of interdisciplinarity throughout the four papers are explained by the flexible, participatory and iterative nature of the action research within the GIS CES; research which has encouraged feedback and adjustments of theory to practice, and vice versa. Moreover, the university exchange between SVT[27] and REEDS[28] has ushered a new framing and vocabulary around interdisciplinarity within this project.

[26] The reflexive prerequisites, defined in Paper 2, are: (a) trying to know each other in the personal dimensions, and sharing experiences, motivations and representations of interdisciplinarity; (b) trying to know each other in the disciplinary dimensions, and facilitating the understanding and acceptance of the various ontological, epistemological, and methodological assumptions; (c) agreeing upon a common definition of interdisciplinarity, making collectively sense of the vast literature and taking into account the two previous points; and (d) collectively defining the objectives and means of the interdisciplinary project, best suited to tackle the issue in the actors' particular research context.

[27] Senter for Vitenskapsteori (Centre for the Studies of the Sciences and the Humanities), Bergen, Norway.

[28] Research Centre for Ecological Economics, Eco-innovation and Sustainable Development, Guyancourt, France.

Instead of talking about interdisciplinarity as a ‘‘meeting of families of cognitive and social matrices’’[29], our research project now employs notions of a cooperative conjugation of ontological, epistemological and methodological dimensions of various disciplines. These terms are more precise and more directly understandable. Moreover, from Paper 3 onwards, interdisciplinarity is tightly linked to authenticity[30], argued to be a key dimension of reflexivity. In the first two papers, authenticity was referred to as ‘confidence’ and ‘respect’; and authentic interdisciplinarity was translated through the idea of ‘true’, ‘deep’, ‘long-lasting’ and ‘effective’ interdisciplinarity.

Thus, the perspective on interdisciplinarity in this PhD has evolved towards discussing it in terms of ‘reflexive interdisciplinarity’, and defined as a *‘long-term cooperation process whereby scientists, in order to mobilise knowledge around a complex and multi-facetted topic, conjugate, in an authentic and reflexive way, complementary disciplinary approaches, in their ontological, epistemological, methodological and social dimensions, through the sharing of tools, methods, approaches and values’*. Interdisciplinarity is a reciprocal learning process: scientists learn about their disciplines and themselves as they confront and compare them with other perspectives and experiences. Reflexive interdisciplinarity occurs in settings that promote authenticity, co-existence, recognition and respect.

b. A more precise framing of reflexivity

The definition of reflexivity proposed in Paper 2 is a first attempt to grasp the several dimensions of the concept. However, it was not enough linked with the idea of ‘reflexive

[29] Paper 2, end of Section 2.

[30] Authenticity is defined in Section 1.4 of this Introduction and in Paper 3.

prerequisites'. We will here formalise the perspective on reflexivity, particularly with regard to its historical evolution.

The term of reflexivity has been defined in various ways over the last century, giving rise to a great variety of coexisting definitions and typologies. These typologies of reflexivity (see, e.g., Wilkinson's three types (1988), Marcus' four styles (1994), and Holland's four levels (1999)) mainly reflect different research purposes, traditions and assumptions. What we propose here is not another typology of reflexivity, but rather to explore how reflexivity, and its associated definitions and objectives, has evolved in the context of some major historical, social, and natural events, that have led both social and natural scientists to reflexively scrutinise their ontological framings, epistemological accesses and methodological interactions with the world. In the context of this PhD, we are particularly interested in exploring when, why and how reflexivity has integrated natural and social sciences, how it has developed, along different paths, within them, and contributed to modify them.

* *Individual and collective endeavour: Reflexivity to highlight subjective representations (1920s - 1940s)*

The notion of reflexivity seems to have first emerged in the 1920s, when the sociologist W. Thomas (1923; 1928) claimed: "If men define situations as real, they are real in their consequences". In other words, by defining a situation, and thus imposing their meaning on it, actors influence the course of the world. In this way, Thomas' reflexive assertion challenged the Vienna Circle's logical positivism, whereby knowledge of the world is based on and achieved through observation and sensory experiences.

In the 1930s - 1940s, the Frankfurt School pursued Thomas' critique of logical positivism through 'critical theory', with, for instance, Horkheimer and Adorno (1944) asserting that men shape the world around them through their mental activities and physical actions (Finlayson, 2005). This assumption according to which our theories on the world do not only describe it, but are part of it and influence it, was further explored by Merton's 'self-fulfilling prophecies' (1948, 1949). He argued that once a prophecy or theory is introduced, actors may modify their actions so that it becomes true: "Convinced that he is destined to fail, the anxious student devotes more time to worry than to study and then turns in a poor examination". Up until this point, reflexivity was essentially an endeavour to bring to light the subjectivity of the individual and collective representations of the world, thus promoting a more integrated and inclusive knowledge construction.

However, three major changes in the 30s-40s prepared the terrain for reflexivity to formally enter into science. First, with the growth of antisemitism in the Second World War, Merton's self-fulfilling prophecies were particularly relevant to explain relations between ethnic groups, with prophecies transforming fears into reality. The only way to break these prophecies was to be reflexive on the deep-rooted origins of antisemitism, and scrutinise the role of science in legitimating these doctrines. Second, during their stay in the United States to escape the Second World War, Horkheimer and Adorno were confronted to industrialisation and capitalism, subjecting people to the control of an increasingly powerful economic system. Instrumental rationality and principles of efficiency had percolated science, which had become an instrument of dominion of men on nature. Consequently, critical theorists claimed that a theory should not only seek the understanding of the world, but should also help transform society by creating social and political conditions more conducive to human flourishing than the present ones. Third, the bombing of Nagasaki and Hiroshima in 1945 led critical theorists to further scrutinise science and its role in facilitating man's mastery and control of his environment.

Since then, reflections upon the responsibility and legitimacy of science have led scientists to consider it as an integral element of society, with obligations towards the latter (Brown, 2001; Merton, 1973).

- *Linear 'benign introspection': Reflexivity to extend scientific legitimacy (1950s - 1960s)*

Reflexivity was taken up as an issue both in social and natural sciences by Popper (1957) and Nagel (1961) in the late 1950s and early 1960s, as a result of two important acknowledgements.

First, based on the self-fulfilling prophecies, it was acknowledged that each individual, and by extension each scientist, has a filtering lens through which he/she sees the world. In other words, the scientist draws on tacit knowledge which distorts the 'true' representation of the world. To face these new questions and challenges about truth, meaning, and knowledge construction, reflexivity was used as a means of making explicit and eliminating the biases of scientists, in order to enhance the robustness of science (Hardy, Phillips, & Clegg, 2001; Weick, 1999). Research methods such as those proposed by Campbell and Stanley (1963), Glaser and Strauss (1967), and Becker (1970), encouraged social scientists to be explicit about their educational, religious, political, cultural and social background, their personal interests and experiences and the means used to achieve their inquiry. These reflexive methods were advocated as ways of producing valid, strong and bias-free results.

The second acknowledgement leading to a broader practice of reflexivity in science, and especially in natural and 'hard' sciences, was formalised by the Frankfurt School. After the bombing of Japan in 1945 and the post-war growth of capitalism and industrialisation, science was no longer considered as an independent entity, disconnected from the rest of the world (Veblen, 1918), but was referred to as having obligations and responsibility towards society. Here again, reflexivity was used to increase the legitimacy of science in the eyes of socio-political actors, by making explicit the motivations behind and purposes of scientific endeavours, in order to avoid harmful research and make sure that scientific progresses where designed to transform society for the better.

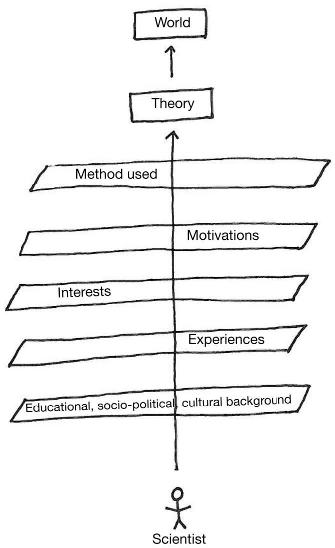

Figure 2: Linear 'benign introspection': Reflexivity to extend scientific legitimacy

As shown by Figure 2, this type of reflexivity, used both in natural and social sciences, takes the shape of a linear, punctual introspection or confession, typically taking place within a specific research project or inquiry. The researcher is a central actor who influences the collection, selection and interpretation of data (Finlay, 2002), and reflexivity is restricted to the scientist's personal background, motivations and tacit practices. The purpose is to make the different layers of the scientist's filter explicit, in order to increase the legitimacy and robustness of his/her inquiry, and more generally to reaffirm, after World War II, the legitimacy of science in the production of knowledge. However, this 'benign introspection' (Woolgar, 1988) does not discuss the 'social contract of science' (Gibbons, 1999). Reflexivity to solve issue-based problems started to emerge in the 1970s.

* *Action - reflection cycle: Reflexivity to solve issue-based problems (1970s - 1980s)*

The period of the 1970s - 1980s particularly highlights the differences between that reflexivity that is integrated to the research methodology, as for the social and human sciences; and reflexivity that does not constitute an obvious part of the every-day research methodology, as for the natural and 'hard' sciences. For the latter, it seems indeed that reflexivity is rather engaged - however rarely in current practice - while operating at the interface between scientific disciplines or at the science-society interface, such as within interdisciplinarity projects or the communication of scientific results to socio-political spheres. These differences in use of reflexivity, as a reflex or habit for social and human sciences and as a potentially appended tool for some extraordinary practices of natural and 'hard' science, partly explain why it is social and human scientists, who by the 1970s - 1980s, had come to the conclusion that scientists' deep-rooted theoretical presuppositions or 'biases' could not be eliminated, even through rigorous research methods or confessions (Hardy, et al., 2001; Mulkay, 1992). The quest for objectivity and value-free science, even for the natural and 'hard' scientists, was impossible (Gouldner, 1970), as science and society were tightly interconnected in a reciprocally influential relationship.

As a consequence, questions on the social construction of natural and 'hard' sciences led sociologists of science to investigate how their knowledge was produced. The 'epistemic communities' of Knorr-Cetina and Mulkay (1999; 1983), Latour and Woolgar's investigations of 'laboratory life' (1987; 1979) and Bloor's 'strong programme' (1976) all examined internal research schemes and values of scientific disciplines. These diverse projects affirmed the influences of the rules, methods and values of a particular discipline on the results produced; scientists are part of a scientific community that sees a portion of the world through a filter constituted by specific ontological, epistemological and methodological frames. Foucault (1970) expanded on the situated position of natural and 'hard' scientists by underscoring the interactions between natural and 'hard' sciences with social, cultural and historical processes. Indeed, through his studies of the history of western thought since the Renaissance, Foucault argued that each historical period has a 'historical a priori' contributing to the organisation of knowledge. This was also emphasised by Bloor who claimed that theories are caused by social factors.

These studies within sociology of science have thus contributed, at least in theory, to the shift within natural and 'hard' sciences, from a reflexivity aiming at removing biases through a set of mechanistic practices (Burrell & Morgan, 1979), to a step of deconstructing science, through which natural scientists achieve a deeper understanding of the origins and implications of their subjective theoretical and methodological choices on the research. As scientific claims must contain some social components, the historical structures of knowledge construction should be explored by natural and 'hard' scientists, in order to trace back their underlying assumptions, beliefs and motivations, and better appreciate their relationship to the world and to other disciplines. Of course, it would be naive to think that all natural scientists, enlightened by the work of their sociologist colleagues started such a step of reflexivity. It is, however, what the sociologists of science of that period indirectly suggested to natural scientists, in order to not forget that society and science are two interacting entities, and that science has a responsibility towards the latter.

This reflexivity takes the shape of an action - reflection cycle (as illustrated in Figure 3) that is limited in time, and focused on a particular issue; setting of a research project for instance. The scientist (natural and 'hard', or social and human) acts on the socio-political and natural

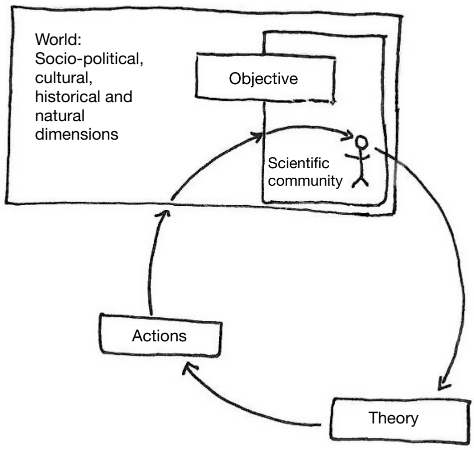

Figure 3: Action - reflection cycle: Reflexivity to solve issue-based problems

world through his/her observations and action, receives the feedback of these changes, and changes his/her theory both in accordance with lessons learned and with society's expectations. This kind of reflexivity is thus particularly adapted to issue-based science, or science concerned with social problems.

The reflexivity of the 1970s - 1980s is not restricted to the examination of the scientists' lives, but scientists are seen as deeply embedded in the world, in turn influencing it and being influenced by it. In discussing the differences between reflexivity in the 50s-60s and in the 70s-80s, we can refer to Woolgar's (1988) map of reflexivity, along a continuum going from 'benign introspection', where reflexivity is punctual and limited to the scientist's background, motivations and practices; to 'constitutive reflexivity', which deepens the benign introspection to allow scientists to acknowledge their irreducible subjectivity and the 'social contract of science'. However, it was not until the 1990s that the participatory and integrated dimension of science started to be questioned, significantly with the emergence of complex global issues.

- *Integrated, adaptive and critical spiral: Reflexivity to empower (1990s - 2010s)*

With the growing awareness of complex global issues and epistemological uncertainties since the 1990s, scientific rationalism on one hand, adopting a modern view of the world seeing humans and nature as separated (O'Brien, St. Clair, & Kristoffersen, 2010), and the dominion of science over other forms of knowledge on the other hand, started to be questioned in recognition that multiple valid perspectives exist, and indeed are required for the study of complexity. This changing and uncertain world provided the context for many authors to advocate for a different kind of reflexivity, more integrated, adaptive and critical.

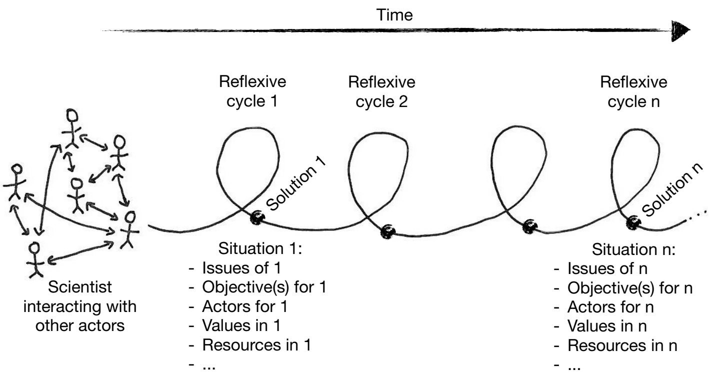

Figure 4: Integrated, adaptive and critical spiral: Reflexivity to empower

In this context of global issues, Gibbons and colleagues (1994), based on Beck's (1986) concept of reflexive modernity, defined reflexivity as an adaptive and critical learning process. This idea was mapped by Linstead (1994) as an unending spiral of deconstructive reflections where there is no established truth nor final objective (see Figure 4).

In parallel with the adaptive and critical characteristic of reflexivity, Funtowicz and Ravetz (1990, 1993), and Denzin and Lincoln (1994) emphasised the importance for it to be integrated, in the sense that scientists should open their research to the scrutiny of the broad scientific community and relevant socio-political actors, in order to remember that their output is only one representation among many other possible.

As scientists are in a powerful position to decide what constitutes knowledge and what does not, this integrated, adaptive and critical reflexivity allows them to acknowledge the plurality of legitimate perspectives around complex and uncertain issues, and aims at empowering the non-scientific actors concerned by these issues by voicing their perspectives and include them into the process of knowledge construction. This kind of reflexivity goes beyond looking at well-defined problems, such as those dealt with in short-term research projects, but constitutes a long-term, continuous and adaptive attempt to work within complexity. As illustrated by Figure 4, each cycle of action-reflection (all together forming an unending spiral) focusses on a particular issue, involves a particular set of actors, and proposes particular objectives and solutions, which may change in the following cycle, as the issue and its broad context evolve. This allows us to visualise the evolution of the decision-making process, and the way in which subsequent iterations learn from prior decisions and actions. This long-term reflexive endeavour aims at implementing incremental changes, supported by adaptive research.

c. Reflexivity in the context of this PhD research

The discussion of reflexivity in this PhD results from the meeting of the GIS CES scientists' and STS action-researchers' expectations, interests and assumptions. Concerning its *form*, first, the action researchers' theoretical positioning on reflexivity and authenticity (see Part 1), and the experiences of the GIS CES scientists of the contributions of "taking the time [to] reflect on [their] motivations and project", combined to give rise to reflexivity in the shape of an action-reflection cycle (see Figure 3). Through feedbacks after confrontation to reality, we aimed at defining reflexivity in a way that was mutually acceptable, and anticipated to promote interdisciplinarity.

Regarding its *nature*, then, our common discussion of reflexivity focussed on four aspects; we decided to reflexively scrutinise: (i) the *method* of our participatory action research itself, (ii) the personal motivations, interests and representations of each *scientist*, (iii) the characteristics of each *discipline* (its ontological, epistemological and methodological assumptions), and (iv) the *role of science* for climate change.

Reflexivity relative to the method, first, was a meta-reflection on the objectives and means of our participatory action research. This reflection aimed at rendering the research process more cooperative, transparent and accessible to the scrutiny of the GIS CES scientists, through iterative feedbacks between them and the action researchers.

Second, reflexivity at the GIS CES scientist's level aimed to foster reflection on how previous personal experiences may influence the representations on and expectations towards interdisciplinarity. The sharing and discussion of personal interests aimed at setting the ground for recognition, respect, authenticity and self-disclosure, as scientists learn about each others' values and concerns.

Third, reflexivity on the discipline aimed to encourage GIS CES scientists to reflect about their disciplinary assumptions, "notice and criticise [their] own [ontological and] epistemological pre-understandings and their effects on research, and explore possible alternative commitments" (Johnson & Cassell, 2001), enabling them to accept their own vulnerabilities and be sensitive and open to new approaches (Strand & Cañellas-Boltà, 2006).

Fourth, as climate change, with its high socio-political stakes, demands a definition of reflexivity that recognises the social context within which the scientific community is nested, our definition of reflexivity included discussions on the role of science for climate change, based on reflections on the 'social contract of science' (Gibbons, 1999). The objective here for climate-related scientists was to acknowledge their subjectivity and the coexistence, in a complex, uncertain and changing world, of multiple legitimate perspectives.

The strength of this definition of reflexivity is that it is grounded both in the interests and assumptions of both the GIS CES scientists and action researchers. In that way, most scientists seemed authentically involved in our reflexive activities, as they had the feeling of being helped while facing their perceived challenges of time, complexity and uncertainty. However, because reflexivity is a long-term learning process, and because of the short-term nature of the PhD (three years), we did not have the time to implement enough iterations in order for the scientists to integrate reflexivity to their research habits, for instance by mobilising it without the action researchers, or in other research projects or settings. In the following section, we address the challenges and implications of 'reflexive' climate-related scientists.

3.3. Paper 3: Introducing a model of 'reflexive interdisciplinarity' for climate change

Drawing upon the exploration in Paper 2, of the contributions of reflexivity at the early stages of interdisciplinary research projects, Paper 3 proposes a model of reflexive interdisciplinarity for climate change, framed as a dialogue between the STS and climate-related communities. This model aims, through the guidance of STS scholars, to help climate-related scientists face the challenges[31] of interdisciplinarity. Based on the idea that reflexivity acts as a 'stabilising pole' in the balancing act of responding to these challenges, the model is articulated around four reflexive tools: 'inaugural contracts', 'writing pauses'[32], 'summary tables' and 'harmonised presentations'. These tools were tested at the 'local' GIS CES level, in two different interdisciplinary projects.

Moreover, by proposing such a 'dialogic' model, Paper 3 triggers two broader debates: that of the challenges and implications of 'reflexive' climate-related sciences on one hand; and on the other hand, that of the current organisation of scientific research, which is perceived as misadjusted to interdisciplinary and reflexive science.

a. 'Reflexive' climate-related sciences: challenges and implications

Paper 3 poses two questions relative to the implications of 'integrating' reflexivity to the research habits of climate-related scientists. First, introducing reflexivity within climate-related sciences may, in parallel with contributions, possibly jeopardise an important part of the current practice of climate-related sciences. Indeed, reflexivity, by encouraging scientists to acknowledge the socially-constructed and increasingly politicised nature of climate-related sciences, and scrutinise the built-in norms and assumptions of their knowledge (O'Brien, et al., 2010; Sarewitz, 2010), could lead them to re-assess the ability of the current

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[31] The challenges of interdisciplinarity, based on the 'local' and 'global' inquiries within the GIS CES, and described in Paper 3, are: (i) dealing with difference: from threat to complementarity; (ii) managing a changing identity while remaining authentic; (iii) finding ways to cooperate while balancing power and freedom; (iv) navigating in complexity and uncertainty without getting lost; (v) being reflexive without being disillusioned; and (vi) learning and cooperating within efficiency-oriented institutions.

[32] Writing pauses were labelled 'writing breaks' in Paper 2. Now, however, the expression 'writing pauses' is preferred, as it better reflects the temporary nature of the interruption in actions and discussions. Indeed, such pauses allow a temporary, individual stepping-back from the interactions and are part of the cooperative process (see Paper 3). 'Break' can be understood as a definitive interruption, disconnected from the cooperative process.

practices of climate-sciences to cope with wicked issues. While we may discuss the contributions that such reflexion could bring, this reflexive scrutiny of the shortfalls of 'normal' climate-related sciences may also, however, lead to paralysing doubts or a breakdown of the dialogue between climate-related scientists and STS scholars, 'threatening' their foundational beliefs and practices.

The second question posed by the introduction of reflexivity in climate-related science is how this could be done. Indeed, in the PhD research, the STS action researchers did not want to *impose* reflexivity on the scientists according to a 'deficit' way, as this could be seen to be counter to the very message of self-reflection tendered. Imposing reflexivity could indeed result in a breakdown of the dialogue between STS and climate-related communities, as well as inefficiency with an approach that does not fit the reality of climate-related scientists.

For these two reasons, the notion of dialogue between STS scholars, having knowledge on the functioning of science, and climate-related scientists, concretely working on interdisciplinary projects, is important. This reflexive dialogue may support a common understanding and construction of reflexive and interdisciplinary science in the context of climate change.

b. New institutions for interdisciplinary, reflexive science?

Paper 3 showed while interdisciplinary and reflexive science demands an important investment in time and energy, scientists engaged in such projects face funding institutions with conflicting agendas and expectations.

In 2000, the European Council decided in its "Lisbon Strategy" to make the European Union "the most competitive and dynamic knowledge-based economy in the world" by

2010 (Aghion, Cohen, & Pisani-Ferry, 2006). To this end, a series of financial laws[33] were applied to European research, aiming to move public management from a resource-based to a result-based approach, and thus keep track and justify, for each specific research activity, the nature and level of resources allocated by the state (Bussereau, et al., 2004). Accordingly, research is divided into identifiable 'missions', themselves sub-divided into 'programmes' (research projects for instance), under the supervision of a given ministry, and characterised by "precise, specific objectives, defined both on the basis of public interest purposes and on the expected results" (RF, 2006). Particular attention is given to the 'efficiency' and 'performance' of these programmes; checked and evaluated through (i) quantified objectives, (ii) indicators of efficiency, (iii) promoted competition among research laboratories, (iv) the concentration of means and resources (for instance in centres of excellence), and (v) merit awards for the most performant and efficient scientists or laboratories (Bussereau, et al., 2004).

This managerial logic presents a barrier, however, to the implementation of interdisciplinary, reflexive science in two ways. First, the division of research in well-defined and relatively rigid entities or projects impedes the interdisciplinary and participatory creation of knowledge, as such structures do not allow spaces for cross-disciplinary meetings, sharing and surprises; the bases of innovation.

Second, expectation of efficiency and performance strongly conflict with the timeframe of interdisciplinary, reflexive science, which necessitates, especially from climate-related scientists who are not familiar with it, an important investment in time, and with concessions made relative to the efficiency within their own discipline. Furthermore, the current

[33] Such as the Constitutional bylaw of August 1st, 2001 on budget acts (Loi organique n°2001-692 relative aux lois de finances), generally known as the LOLF.

organisation of research is not adapted to the attitudes and values promoted by interdisciplinary and reflexive science. Indeed, cooperation, authenticity, and the recognition of a plurality of legitimate perspectives can hardly arise in a context of division, increased specialisation, and competition.

The results of this PhD research implies that a more inclusive, adaptive and reflexive organisation of science, which encourages long-term dialogue across disciplines, and between STS and climate-related communities, is a necessary precursor fostering interdisciplinary and reflexive science that fits the reality of climate-related scientists, and that provides outputs that can be mobilised at the science-policy interface by the various communities concerned by climate change.

3.4. Paper 4: Encouraging reflexive dialogue on the science-policy interface

Climate change as a ‘wicked’ problem has put science under the ‘magnifying glass’; demanding of climate-related scientists a more adaptive, integrated, and holistic understanding of interconnected and constantly evolving social-ecological systems. To this degree, climate change has been instrumental in the emergence of interdisciplinary practices. However, one of the most important (if not *the* most important) facets of this interdisciplinary science for climate change must be the way it is communicated. Therefore, it was important that this research finished by examining how interdisciplinary outputs find expression at the science-policy interface.

Paper 4, building on the participatory action research at the 'local' level of the GIS CES, attempts to establish bridges between climate-related scientists' representations of the science-policy interface, and STS scholars' descriptive and normative theorisation of this interface. Important discrepancies across these two communities where noted, particularly on the ontological and epistemological representations of climate, giving rise to divergent ideas on the actions and interactions at the interface. In order to build an interface both better anchored in the research context of climate-related scientists, and increasingly inspired by STS insights on complexity, uncertainty, plurality or reflexivity, the paper invites a reflexive dialogue between the two communities.

It would be interesting to take this discussion further by starting from the emerging STS literature that shows how scientists who engage with the general public and decision-makers are among those who have the most successful scientific careers (see, e.g., Jensen, 2011; Jensen, Rouquier, Kreimer & Croissant, 2008), and explore the extent to which the dialogue facilitated by reflexive interdisciplinarity may positively influence the interactions within the institutional setting presented by the science-policy interface. Indeed, being interdisciplinary in a reflexive way and interacting with actors at the science-policy interface could be seen as nurturing each other along an evolving, reciprocal relationship. Even though this PhD has not focussed on this specific aspect, its conclusions legitimise further research in this direction, for three reasons.

First, *reflection on the role of science for climate change*, triggered by reflexive interdisciplinarity, may help climate-related scientists to perceive their research in the broader context of the social and political realities. In this way, scientists could be conceived to engage in questions on how to make scientific outputs socially relevant, how to communicate them, and how to deal with public scrutiny. A dialogue between STS and climate-related scientists could provide support in facing and overcoming such challenges.

Second, by encouraging scrutiny of the built-in assumptions, representations, and indeed limitations of each scientific discipline, reflexive interdisciplinarity highlights at once the *independence and interdependence of knowledge systems*, with the attendant *need to cooperate* in the face of complex and uncertain issues. Subsequent attitudes of openness and sensitivity to other knowledge systems may constitute the first step to reciprocal interactions between scientific and non-scientific perspectives, with implications for how knowledge is mobilised at the science-policy interface. Indeed, as scientists are encouraged to reflect on the socially-constructed nature of their knowledge, and thus extend legitimacy to other perspectives, so may they realise the importance of negotiation in arriving at socially-relevant knowledge. However, Paper 4 shows a predominance towards framing the science-policy interface according to a 'deficit model', where science remains the most legitimate source of knowledge for supporting decision-making processes. Here again, a dialogue between STS and climate-related scientists could contribute to a new, collectively acceptable interface.

Third, reflexive interdisciplinarity is a *pragmatic learning process* whereby scientists concretely try to overcome challenges of language, asymmetry, dependence and time. Thus, reflexive interdisciplinarity may provide the first practical lessons to a broader dialogue, that of scientists and non-scientific actors: "When you want to communicate with the general public, with decision-makers, or with a scientist outside of your field, in all these cases, you have to [...] always be attentive to your interlocutor: how familiar is he/she with what I am talking about? Do I refer to concepts that are new for him/her?"

In conclusion, this PhD reveals promising directions for future research on how reflexive interdisciplinarity may have influences beyond the boundaries of science, to contribute to an authentic and reciprocal dialogue among all actors at the science-policy for climate change. In this way, reflexivity could be seen as engaging society as a whole to collectively formalise common values, priorities and practices along which to apprehend climate change and its various impacts; and hence to reflect upon the science-policy interface they aspire to.

Conclusion and need for further research

This PhD research aimed at achieving an increased understanding of interdisciplinarity for climate change, both theoretically and procedurally, particularly through the lens of reflexivity. Based on the few studies which have discussed interdisciplinarity in terms of 'reflection' or 'reflexivity' (Klein, 2004; Romm, 1998; Wickson, et al., 2006), this PhD proposed to link, in an innovative way, reflexivity to interdisciplinarity through a dialogue between climate-related scientists and STS scholars. Indeed both communities bear strongly complementary expertise: while the scientists are active in interdisciplinary projects, STS researchers, who study science and its interactions with society, envision the challenges of interdisciplinary dynamics and of interactions at the science-policy interface.

This PhD thus emphasised the importance of an authentic and reciprocal dialogue between the two communities of STS researchers and climate-related scientists, in order to give effect to 'reflexive interdisciplinarity'. Reflexive interdisciplinarity has much to offer in terms of authentic interactions and innovative outputs within science, and supporting the collective scrutiny of the role and shape of science for climate change.

Beyond this PhD project, a broader discussion which deserves further attention is that of the contributions of reflexive interdisciplinarity to the implementation and development of interactions between actors at the science-policy interface. Indeed, as it has been explored throughout this research, reflexive interdisciplinarity encourages cooperative attitudes such as authenticity, openness and recognition within science. These attitudes may open possibilities for implementing a science-policy interface where scientists together with non-scientific actors such as decision-makers, civil society, local and traditional communities, collectively construct and evaluate knowledge on climate change, and discuss the actions to implement.

Further research on this idea of reflexive interdisciplinarity is required to show some empirical justifications for the possibility of a dialogue-based, open and respectful coexistence of scientific, socio-economic and political stakeholders at the science-policy interface for climate change.

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Publications

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Paper 1

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Dissipating the fuzziness around interdisciplinarity: The case of climate change research

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Disambiguation

Dissipating the fuzziness around interdisciplinarity: the case of climate change research

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Abstract

Late last century saw an increasing realisation of significant environmental changes on a global scale, characterised by high levels of dynamism and complexity, and important stakes. Perhaps foremost among these global changes is the issue of climate change, which will form the context of this paper. The complexity that accompanies climate change translates into a need for scientific interdisciplinary approaches, first to achieve a more integrated and comprehensive vision of the issues, and second to better inform the decision-making processes. However, achieving an interdisciplinary setting can be an elusive goal, owing particularly to the contextual nature of interdisciplinary dynamics, which makes it difficult to follow any means of 'best-practice'. Nevertheless, a common understanding of interdisciplinarity is important for researchers and practitioners to ask comparable questions and explore similar hypotheses, thus enabling them to build on what they already know, and advance the practice and scholarship of interdisciplinarity. To this end, both the scholarship and practice of interdisciplinarity have shown the need for actors who commit to interdisciplinarity to reflect on four complex features. They are its definition, origins, objectives and means. The purpose of this paper is to explore and clarify these four features in order to provide route-markers to a more effective and long-lasting implementation and structuring of complex interdisciplinary dynamics. Mobilising dialogue between theory and practice, this paper will draw from both an overview of the literature, and qualitative research undertaken in the Ile-de-France region within the Scientific Consortium for Climate, Environment and Society (GIS CES), which is attempting to conduct interdisciplinary research on the impact of climate change on society.

Keywords: Interdisciplinarity, complexity, reflexivity, climate change.

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1. INTRODUCTION: FOUR COMPLEX FEATURES OF INTERDISCIPLINARITY

Researchers and practitioners who commit to interdisciplinarity know that its definitions, origins, objectives and means are surrounded by fuzziness and complexity. Exploring these four complex features is an essential prerequisite for those involved in interdisciplinary projects. To help researchers and practitioners with this, the paper tries to dissipate the fuzziness around these complex features of interdisciplinarity by provoking at times a dialogue between literature and practice. Qualitative research undertaken in the Ile-de-France region in March 2009 within the Scientific Consortium for Climate, Environment and Society (GIS CES), provides some insights into the representations and experiences of 15 scientists who are working on different aspects of climate change (climatology, hydrology, ecology, health, social sciences and humanities), and have been brought together for research projects on the impact of climate change[1].

2. DEFINITION: FOUR LEVELS OF INTERACTION

The first stage for researchers and practitioners who commit to a cross-disciplinary project is to define and situate the degree of interaction among disciplines involved, and reflect on a harmonised definition of interdisciplinarity. Complexity is added by the fact that the degree of interactions demanded between disciplines depends on the purpose of the interdisciplinary project. Indeed, the degree of cross-disciplinary interaction chosen will first influence the specific rules and values to structure the interactions, and second shape the objectives of the project, whether they are substantive, procedural or contextual.

Cross-disciplinary interactions can be characterised across four different levels of integration (Figure 1), among which practitioners and researchers must differentiate. First, pluridisciplinarity encourages several disciplines to coexist within the same entity (e.g., a university), without necessarily requiring exchanges among them. Cross-fertilisation does not exist. Multidisciplinarity is the meeting of distinct disciplines around a common study theme, although each is permitted to retain its specific rules, methods and tools. This can be illustrated by the organisation of the IPCC research on climate change around three working groups that study different aspects of the same object: (i) its scientific dimensions, (ii) its impact on the social, economic and environmental spheres, and (iii) the development of adaptation and mitigation policies. Between the IPCC working groups and for multidisciplinarity in general, cross-fertilisation is limited. Interdisciplinarity allows the exchange of concepts, rules, methods and tools among different disciplines in order to achieve a global understanding of a common theme. Again, an example can be drawn from the IPCC experience, where the 'Special Report on Emissions Scenarios' (SRES) provides prospective scenarios as a result of dialogue between climate scientists and economists. In this case, cross fertilisation leads to a progressive blurring of disciplinary boundaries. Transdisciplinarity is a process of integration that overcomes disciplinary boundaries for a more complete understanding of a complex world. The 'Earth System' models illustrate transdisciplinarity, in the way they aim to integrate the environmental, social and economic dimensions required to understand the functioning of the Earth, to better anchor science in social and political realities, and to respond to their expectations. It differs from interdisciplinarity to the extent that a new discipline is created, with its own codes and tools.

Having differentiated among four degrees of integration, this paper focuses on describing interdisciplinarity, beginning with a reflection on the notion of disciplines.

According to the literature, even if disciplines are not stable areas, they are characterised by specific particularities. Klein (1996) defines disciplines as "dynamic systems" that evolve and adapt to changing environments, ideas and influences, by producing reformulations of their knowledge. These dynamic systems differ from each other by specific values, language and rules, where practitioners have different attitudes, habits, and practices. Disciplines are thus compared by Bauer (1990) and Ferris (2003) to different cultural groups. 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 1962).

This leads us to draw a definition of interdisciplinarity that is structured around four main dimensions. First, interdisciplinarity aims to structure different sources of knowledge around a common topic. For Klein (2004) interdisciplinarity is a process that begins with an issue of concern to approach complex questions that specialised disciplines cannot answer. Jakobsen (2004) and Keesey (1988) evoke the second dimension of interdisciplinarity — the sharing of tools, methods and

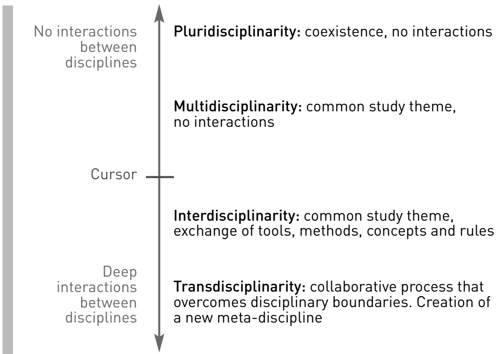

Figure 1. Four levels of cross-disciplinary interaction. The interactions between disciplines can be classified according to four points on a scale, along which researchers have to explicitly place their cursor. Source: Inspired by Klein (1996) and Jakobsen (2004)

1 As the purpose of the paper is to explore and clarify the complex features of interdisciplinarity, the detailed context and results of the qualitative research are not presented here in depth. Nevertheless, while waiting for their publication, parts of the research are accessible on the GIS CES website: http://www.gisclimat.fr.

approaches across disciplines — as an evolving process of knowledge construction. The more distant and divergent the disciplines are, the more time practitioners need in which to learn about each other's language and methods. To achieve this interfacing of different disciplines, there is a need for cooperation, as the third dimension, which is emphasised by Hunt (1994). She defines 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". Recognition that every discipline brings a valuable perspective, and horizontality in the participation, contribution and efforts made by the disciplines, are the basis to a cross-disciplinary cooperation. Finally, the fourth dimension, reflexivity, is illustrated by Romm (1998). Being reflexive on one's own discipline is necessary to implement interdisciplinarity. The fifth section will illustrate these points with experiences of the GIS CES scientists.

The objectives of an interdisciplinary project are associated with how actors define interdisciplinarity. If there is no agreement on a definition, actors may raise conflicting objectives that will impede the progress of the project. Once an exploration of the complex notion of interdisciplinarity is led, and the 'cursor' placed along the interaction line, the construction of objectives that are coherent with the degree of interaction between disciplines involved should become more straightforward.

3. ORIGINS: THREE MAIN UNDERLYING PURPOSES

Having defined interdisciplinarity, a second complex feature of it is its origins. Indeed, knowing where interdisciplinarity comes from and why it has emerged, provides insights into its philosophical and theoretical underpinnings. As we will see, the participants within the GIS CES were often confronted by issues that forced them to reflect on the origins of interdisciplinarity.

According to Gusdorf (1983), Klein (1990) and Berger (1972), interdisciplinarity emerged in the Middle-Ages with the creation of the university and its specialised academic branches, introducing the need to build bridges between them to answer complex questions. Ferris (2003) believes that the Enlightenment period has then led to a deeper questioning of the representation of knowledge and its disciplinary divisions. Such questioning was developed by GIS CES climate scientists who studied the impact of climate change on grape harvesting dates: "Not taking into account historical elements in our climate models was leading to biased results. Indeed, drawing from a 300-year set of data, 30% of the harvest times had an anthropic origin: wars and epidemics for instance. The forcing of our models was completely erasing the human dimension".

As Sarewitz (2004) argues, scientific disciplines have become so specialised that they lose their coherence. No perspective is 'wrong' by its own measures, however they are all incomplete without the other perspectives. Indeed, Jorgensen, Patten and Straskraba (1999) describe how the emergence of quantum physics in the early 20th century provided a scientific basis for such pluralism. "Due to observational limitations, two or more different views could be equally valid. There is not one true, unambiguous picture of nature, but many pictures based on different observations".

Consequently, post-modernism has encouraged the establishment of interdisciplinarity by providing a critique of the notion of universal knowledge, by focusing on the complex and uncertain nature of reality, and by highlighting and interrogating the social, political, economic and cultural dimensions of science (see e.g., Henrickson (2002) and Rudel (1999)). Funtowicz and Ravetz (1990) showed how a complex system can lead to significant uncertainties that force society to turn to an alternative and inclusive science that seeks an integrated view beyond reductionist disciplinary boundaries to include alternative knowledge systems. For the scientists of a GIS CES project that traverses health, climate sciences and physics, the reduction of uncertainties is one of the main reasons that led them to work together. "It is very difficult to quantify the exact, direct impact of pollution on pregnancy. Therefore, to promote preventative policies and limit the risks to pregnant women, health data must be absolutely reinforced by strong physical and climatic data".

From the origins of interdisciplinarity, researchers and practitioners gain insights of its foundation statements and assumptions. First, complex issues require multiple perspectives to be explored and anchored in social and political realities. Second, some knowledge falls between disciplines, and can only be approached through an interdisciplinary perspective. Third, there is no universal knowledge, and multiple valid perspectives exist. In the following section, a classification of these objectives is proposed.

4. OBJECTIVES: TWO POLES, THREE TYPES

The exploration of the definition and origins of interdisciplinarity has already provided insights into its objectives, the third complex feature. Reflection and deliberation on the objectives of an interdisciplinary project enable researchers and practitioners to more clearly and legibly design the means to enact these objectives.

While this may seem relatively intuitive, researchers and practitioners must be aware of the multi-classification of objectives. Van Den Hove (2006) proposes a classification into three types — substantive, procedural and contextual. These three types of objectives and their combinations depend on the project's design, i.e., the disciplines involved, the length of the project, and the frequency of the meetings.

Substantive objectives follow the idea of improving the scientific knowledge around a complex problem, dissipating the uncertainties around it, and exploring the "black holes" that it may contain to achieve a better understanding of the cross-object.

Again, the IPCC can be used by way of illustration. The IPCC as a scientific institution is in pursuit of substantive objectives. IPCC scientists try to achieve a more comprehensive vision of climate and attempt to reduce uncertainties regarding climate projections, in order to implement effective policies.

Procedural objectives seek to rethink the ways to work across disciplines, and to establish a framework for interdisciplinary cooperation. Both substantive and procedural objectives are goals at the project scale. The IPCC's working groups that explore "cross-cutting issues" constitute examples of procedural objectives, because they aim to implement new frameworks and methodologies to work across disciplines on specific issues that require the insights of several disciplines, such as ice sheets and sea-level rise, or the evaluation of uncertainties and risks inherent in climate change.

Contextual objectives are goals on a larger scale. They aim to change the global context of action and interaction, for instance, by pursuing changes in institutional functioning. Typically, the GIS CES is an example of contextual objectives, in the way in which it intends to change the global change research environment, by fostering interdisciplinary interactions, and by seeking to build networks that change the scientific landscape.

Creutzer (2002) proposes a second way of classifying these substantive, procedural and contextual objectives, by proposing an organisation along two poles — the social and epistemological poles. The social pole tends to redefine the role of science within society, particularly by anchoring scientific research in social and political realities. 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. The number of possible motivations along the scale between those two poles is almost infinite.

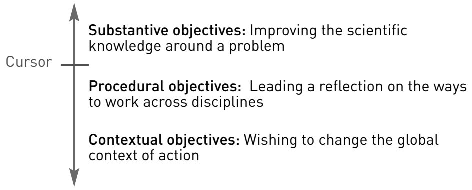

Figure 2. Objectives: three types. Example of a classification of research objectives according to their nature.
Source: Inspired by Van Den Hove, 2006

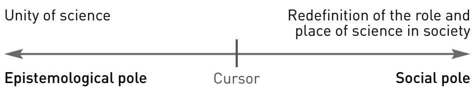

Figure 3. Objectives: two poles. Example of a classification of research objectives along the social and epistemological poles.
Source: Inspired by Creutzer, 2002

In both classifications, an explicit position of the 'cursor' along the line of the objectives is important to enable researchers and practitioners to implement means that are coherent with their objectives.

The practical GIS CES experience, and particularly one of the interdisciplinary projects on the impact of climate change on the frequency of skin cancer, highlights the importance for those who are committing to interdisciplinarity of reflecting on and making explicit the objectives of their project. Indeed, the project, by gathering together medical doctors, physicists and climatologists, reveals the coexistence of the two poles and two of the three types of objectives, without an explicit placing of the 'cursor'.

The objectives situated around the epistemological pole are simultaneously substantial and procedural. They are expressed by a desire to restructure and establish a better network of communication among scientific fields to respond to complex problematic. The medical doctors, physicists and climatologists showed a willingness to generate new synergies between their disciplines; implement a "shared culture", an interface where their "communities can take inspiration from data, results, or methods of the other disciplines involved, to design more effective and comprehensive approaches to complex topics". Moreover, the desire to integrate different disciplines is a way to gain credibility, and to help researchers to "reinforce the qualitative data from the medical or social fields with quantitative data from physics and climatology", thus allowing their contextualisation through multiple perspectives and constructions.

Around the social pole, procedural and contextual objectives are found. Procedural objectives mainly found expression in the willingness of the medical doctors, physicists and climatologists to open their disciplines to socially-rooted questions, an objective being to take part in a movement that responds to the "fears of policymakers and society regarding the increase of skin cancers", through scientific collaborations that strengthen the nature of the results and give them more depth. For the GIS CES scientists, the achievement of an effective social and political message would be one of the successes of the project; "One of our objectives is to draw risk maps, informing people and decision-makers of the dangerous periods". Thus, interdisciplinarity is considered to be a means by which to reflect on the role and responsibilities of science regarding society, one respondent noting, "linking my scientific research on climate to social aspects reminds me why I am a researcher". Contextual objectives translate into a wish to be at the core of interdisciplinary dynamics on a larger scale (e.g., "Our project will be successful if it allows other interdisciplinary projects to take root in ours"). Most of the current GIS CES projects are intended to form the bases for future projects and launch deep interdisciplinary interactions on a larger, European or world-wide scale, to address a broader social demand.

Having different types of objectives within the same project does not impede interdisciplinary dynamics, however problems arise when the nature of the objectives is not made explicit. Indeed, it is the main source of "misunderstanding and disagreement over the ends of the project, and therefore the means to such ends". For instance, it took one year for the medical doctors to "finally understand the objectives and motivations of the physicists". This highlights the importance for researchers and practitioners to reflect on and agree on objectives that are appropriate to their research design. The following section explores the means to achieve interdisciplinary objectives.

5. MEANS: TWO ESSENTIAL VALUES

The means to accomplish cooperation between actors and integration of knowledge across disciplines are nearly infinite. Indeed, mechanisms or means to achieve interdisciplinarity strongly 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, Hels et al. 2004). For instance, Bramsnæs et al. (1997) found that working across disciplinary boundaries the first time takes much longer than on subsequent occasions, and Hatch (1997) assumes that a larger group makes it more likely for subgroups to form, and thus impede the interdisciplinary dynamic at the project scale. Hence, the fourth and last complex feature of interdisciplinarity that researchers and practitioners need to explore is the means to implement interdisciplinarity that are adapted to their particular project context.

The literature provides some formalised frameworks on the ways to implement interdisciplinarity. For instance, Davis (1988) identifies four steps to obtaining interdisciplinarity: (1) Agreeing to abstain from approaching the topic along the lines of their disciplinary method alone; (2) Trying to formulate the global question together; (3) Translating the global question into the specific language of each participating discipline; (4) Agreeing-upon an answer that must integrate all particular answers available. However, as previously noted, the paths to follow in order to implement interdisciplinarity are strongly dependant on human and environmental criteria, or capacities, that will facilitate or limit the implementation of cross-disciplinary practices.

The GIS CES experience highlights two critical values that might help researchers and practitioners involved in interdisciplinarity to structure their project in a more systematic way. They are confidence and reflexivity.

According to the GIS CES scientists, confidence seems to be an important requirement for interdisciplinarity. Building confidence starts with an exploration phase at the beginning of the project, from 6 months to one year, where the feasibility of the project is evaluated and the scientific question formulated. More importantly, this period is an opportunity "to get to know each other in the personal and disciplinary dimensions", and hence foster an area of trust and openness to collaboratively reflect on and discuss the tensions that may occur in intercultural and interdisciplinary settings. From a practical point of view, this means that an interdisciplinary project must permit participatory management of logistical questions (i.e., the frequency and place of the meetings and the practical roles of every participant) in order to facilitate communication among the group members, and create a permissive atmosphere that fosters lively dialogues.

The second value that is important in building interdisciplinarity is reflexivity. To avoid "reinventing the wheel for each new project and for each new problem", which is a frequent problem, documentation on the construction and evolution of the collective dynamics within a group, as in a logbook for example, seems to be useful. A logbook can permit researchers and practitioners to return to previous steps and change their orientation, if necessary, thereby creating precious roadmaps for future projects or other researchers. As well, it allows researchers and practitioners to reflect constantly and explicitly on the interactions between the group members and the impact of the projects on the problem explored. Reflexivity also acknowledges that an interdisciplinary project evolves over time, meaning that researchers and practitioners should reflect on "alternative means that help the project adapt to new settings", and achieve its objectives.

6. ONE CONCLUDING LESSON: REFLEXIVITY

In light of the GIS CES experience, this paper has shown the importance for researchers and practitioners of being reflexive on the four complex features of interdisciplinarity to implement long-lasting and effective interdisciplinary dynamics. Furthermore, interdisciplinarity implies an acknowledgement that disciplines not only have different subjects and methods, but also different visions of truth and the world. Researchers and practitioners must therefore transcend unconscious thinking processes by reflecting on their personal habits, values, interests and representations. A tool that fosters and structures reflections on interdisciplinarity is the use of metaphors. It permits, according to Ferris (2004) and Klein (2004), the representation of disciplines and their links in an integrated way. By using metaphors, the representation of knowledge is not objective, but based on experiences and expectations. Therefore, inter-disciplinarity must be strongly linked with a process of reflexivity from the researchers and practitioner.

Finally, being involved in a cross-disciplinary dialogue and learning about methods, data, and values of other disciplines, helps researchers and practitioners to reflect on their own discipline and from the rules that define it. Interdisciplinarity and reflexivity are thus an intertwined, evolving relationship, with Hunt (1994) observing, "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 has repercussions in the various disciplines involved in a project, thus instilling changes in the scientific research towards the integration of different kinds of knowledge — a necessary step in responding to social expectations towards climate change.

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Paper 2

Anne Blanchard and Jean-Paul Vanderlinden

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

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II

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.

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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 lIe-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 lIe-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 policy 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

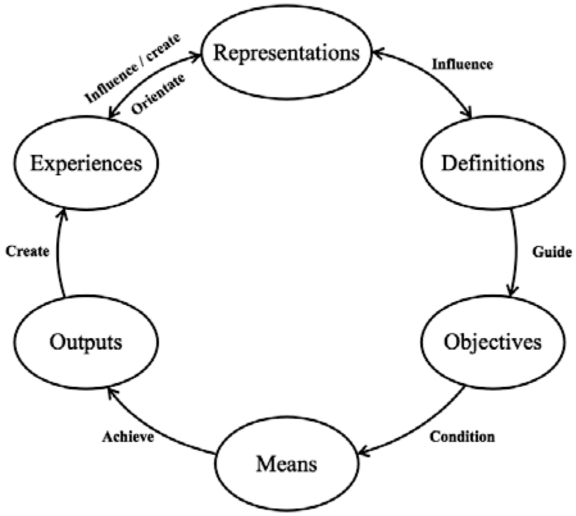
b getting to know each other in the disciplinary dimensions

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, unexplicated motivations seem to lead to misunderstandings within the selection and building of projects; for instance, it took one year to 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 members 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 climatologist, 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.

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Paper 3

Anne Blanchard

Overcoming the challenges of interdisciplinarity? A model of reflexive interdisciplinarity for climate change

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III

Overcoming the challenges of interdisciplinarity?
A model of reflexive interdisciplinarity for climate change

Anne Blanchard

Abstract

Climate change demands an understanding that transverses scientific disciplines, but giving effect to such interdisciplinarity is difficult. This paper emphasises the contributions of reflexivity to interdisciplinarity, and asserts that scientists involved in interdisciplinary projects would benefit from entering into a structured, long-term reflexive process. In particular, it emphasises the specific expertise of researchers from Science and Technology Studies for guiding such reflexivity, by instigating reciprocal dialogue with those scientists engaged in interdisciplinarity. To this end, the paper follows participatory action research undertaken with two interdisciplinary projects within the French 'Scientific Consortium for Climate, Environment and Society'. It takes as its point of departure six central challenges to interdisciplinarity identified by scientists within the projects, before proposing and testing a model of 'reflexive interdisciplinarity' according to the interplay of four tools; 'inaugural contracts', 'writing pauses', 'summary tables', and 'harmonised presentations'.

Keywords: Challenges of interdisciplinarity, model of reflexive interdisciplinarity, climate change

Introduction

In recent years, interdisciplinarity has become a 'buzzword' widely used by researchers and practitioners, as well as by policy-makers and funding institutions (Schmidt, 2007). At the same time, actors involved in interdisciplinarity are confronted with a vast and confusing literature on the many ways of creating and mobilising interdisciplinary knowledge; with recommendations extending from practical points, such as the size of the project and communication tools (see e.g., Hatch, 1997); to more abstract attitudes, promoting 'openness', 'respect', 'reciprocity' or 'recognition' (see e.g., Bramsnæs et al., 1997; and Jakobsen et al., 2004). However, giving effect to these principles in practice presents enormous challenges. This paper asserts that scientists involved in interdisciplinary projects on climate change could benefit from entering into a 'guided' long-term reflexive process; asserting that in instigating and guiding such a process, the specific expertise of scholars in Science and Technology Studies (STS) are important. Here we present such a reflexive process in terms of reciprocal and authentic dialogue between climate-related scientists[1] engaged in interdisciplinary projects, and STS action researchers, who together debate how best to develop interdisciplinary dynamics for a particular issue and research context.

The paper has two objectives. We first explore the challenges met by scientists involved in interdisciplinarity for climate change; drawing on the findings of a participatory action research undertaken in France from 2008 to 2010, following two interdisciplinary projects. Second, in recognition of these challenges, the paper interrogates the contributions of long-term reflexivity to interdisciplinarity, by presenting a model of reflexive interdisciplinarity based on a dialogue

[1] In this paper, when we talk about 'climate-related scientists', we do not only refer to the natural and 'hard' scientists concerned with the study of climate change (i.e.: meteorologists, ecologists, hydrologists, geologists, physicists, mathematicians, etc.); we also refer to the scientists from social and human sciences, economics, health and history, involved in research on climate change.

between STS action researchers and climate-related scientists, and articulated around four reflexive tools[2]: an 'inaugural contract', 'writing pauses', 'summary tables', and 'harmonised presentations'.

The paper will be structured according to three parts. Part 1 presents the participatory action research that sets the context for the discussion in this paper. More particularly, we give insights into the two interdisciplinary projects from which the results have arisen. Part 2 explores six types of challenges to interdisciplinarity for climate change, that can be discussed in terms of equilibrium exercises between the often paradoxical dimensions of interdisciplinarity. Finally, in Part 3, we present our model of 'guided' reflexive interdisciplinarity for climate change, with an emphasis put on the contributions of a reciprocal dialogue between STS scholars and climate-related scientists. The reflexive tools are defined in this part.

1. Context and methodology

1.1. Participatory action research with STS action researchers and climate-related scientists

This paper is based on a two-year participatory action research, characterised by iterative cycles of individual and collective reflections and actions, and undertaken by two STS action researchers[3] with climate-related scientists[4] from the French Scientific Consortium for Climate, Environment

[2] The term 'reflexive tool', used in this paper, echoes the now well-known discussion on deliberation support tools.

[3] Anne Blanchard (the author) and Prof. Jean-Paul Vanderlinden.

[4] See footnote 1. From now on, when we talk about 'climate-related scientists', we refer to the scientists who participated in our participatory action research.

and Society (GIS CES). This Consortium is in charge of funding and supporting interdisciplinary projects between 16 national research laboratories in natural sciences, economics and health. These projects explore the various impacts of climate change on the social, political, economic and environmental spheres[5].

The first stage of our action research[6], engaging the entire GIS CES Consortium, consisted in the establishment of a common definition of interdisciplinarity and its means of implementation. Based on failures to initiate and develop interdisciplinary dynamics in some of the GIS CES projects, we collectively endorsed principles of reflexivity, and advocated for a reflexive 'incubation phase'[7] at the preparatory stages of interdisciplinary projects. However, though this short-term reflexive endeavour comforted us all in our first hopes and intuitions, it did not bring the results we expected in terms of authentic interdisciplinary interactions. Nonetheless, in recognition of the fundamental contributions of reflexivity to interdisciplinarity, and a realisation that it is a long-term learning process, we together asserted that the reflexive step had to be a long-term endeavour, for at least the lifetime of the interdisciplinary project.

Therefore, in the following stages of our participatory action research, we sought to nurture a long-

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[5] For further informations on the GIS CES, see: Blanchard, A., & Vanderlinden, J.-P. (2010). Dissipating the fuzziness around interdisciplinarity: The case of climate change research. Surveys And Perspectives Integrating Environment and Society (SAPIENS), 3(1); or refer to the GIS CES website: http://www.gisclimat.fr/en

[6] Described in our forthcoming paper 'Prerequisites to interdisciplinary research for climate change: lessons from a participatory action research process in Île-de-France', International Journal of Sustainable Development (IJSD).

[7] As described in our forthcoming paper (Blanchard & Vanderlinden, 2011, forthcoming), the incubation phase is a period at the beginning of an interdisciplinary project, giving the opportunity to its members to: (a) try to know each other in the personal dimensions, and share their experiences, motivations and representations of interdisciplinarity; (b) try to know each other in the disciplinary dimensions, and facilitate the understanding and acceptance of the various ontological, epistemological, and methodological assumptions; (c) agree upon a common definition of interdisciplinarity, making collectively sense of the vast literature and taking into account the two previous points; and (d) collectively define the objectives and means of the interdisciplinary project, best suited to tackle their issue, in their particular research context.

term reflexive dialogue between STS scholars and climate-related scientists, following two particular GIS CES projects. The 'CCTV' project[8] combines sociological, political, geographical, climatic and ecological approaches to understand urban 'greenways'. The 'HUMBOLDT' project[9] engages climate scientists and biologists to model climate change and the evolution of biodiversity in the French Alpine region. We, the STS action researchers and climate-related scientists of both projects, explored the contributions of reflexivity to 'overcome' the challenges of interdisciplinarity; developing and testing a model of long-term reflexive interdisciplinarity, based on four tools; inaugural contracts, writing pauses, summary tables, and harmonised presentations. Through the action research, we collectively discussed the effects of this model on interdisciplinary dynamics through individual interviews and focus groups. When needed, we adjusted the tools to better fit the climate-related scientists' reality, encouraging us to scrutinise our perspectives on reflexivity.

1.2. Thematic analysis of oral and written data

Our results are based on numerous sources of data, both oral and written, scattered across the two different projects. The written data, collected through writing pauses and summary tables, were gathered after each meeting and kept by the action researchers. The climate-related scientists had the choice to write in French or in English. As for the oral data, interviews and focus groups were run in French, recorded, and fully transcribed. The interviews lasted between 30 minutes to one hour each; the focus groups, approximatively two hours.

The transcribed oral data and written data were analysed by the same method of 'thematic analysis';

[8] For further informations, see the website http://www.gisclimat.fr/en/project/cctv

[9] For further informations, see the website http://www.gisclimat.fr/en/project/humboldt

a ‘manual’ analysis organised around categories, sub-categories and links between these various entities. To illustrate our ‘thematic analysis’, let us take the example of the writing pauses of the CCTV participants. We first classified the answers under categories representing the theme of each question. These categories were labelled ‘motivations for participating to the project’, ‘previous experiences of interdisciplinarity’, ‘expectations at this early stage of the project’, ‘observed convergences / divergences between the participating disciplines’, and ‘questions to other disciplines’. Two additional readings allowed the emergence of sub-categories, refining in more detail the results of each category. For the category ‘motivations’, we identified the following sub-categories: ‘scientific interests’, ‘financial interests’, ‘social responsibility of science’, ‘networking’ and ‘curiosity’. The writing pauses were read several times, to validate the regular use of the categories, and their completeness. After this thematic analysis, a short report was written by the action researchers, and sent to the participants. These reports aimed at preparing the following meetings.

2. The challenges of interdisciplinarity

The participatory action research revealed six main challenges of interdisciplinarity for climate change. These challenges can be pictured as six equilibrium exercises between the paradoxical dimensions of interdisciplinarity, where scientists acrobatically balance (i) difference and complementarity, (ii) self-evolution and authenticity, (iii) freedom and power (or creativity and dependence), (iv) uncertainty and innovation, (v) reflexivity and disillusion, and (vi) learning and efficiency. In the face of these challenges, reflexivity can be seen as the stabilising pole which helps scientists involved in interdisciplinarity to perform their project.

2.1. Dealing with difference: from threat to complementarity

Dealing with the puzzling nature of *difference*, which simultaneously threatens scientists' identity and legitimates their own contributions, is one of the first challenges met by interdisciplinary actors. This challenge implies three steps: (i) the recognition, (ii) definition and (iii) 'management' of the ontological, epistemological and methodological differences across the disciplines involved in a same project.

First, if the recognition of divergences across various disciplines is the starting point of interdisciplinarity - indeed, difference, and the resulting complementarity, constitute the essence of interdisciplinarity - time is rarely taken for acknowledging and reflecting on them. In our research, we frequently observed the tendency of scientists to 'forget' such differences that had not been previously formalised and discussed. Some would, for instance, use jargon-laded expressions and acronyms, or refer to very specific tools or databases that other disciplines were not familiar with. For example, in HUMBOLDT, a biologist shared in an individual interview his concerns regarding this issue: "[Climatologists] talk about their data like it is obvious to everyone. But it took me 6 months to understand how to use their databases!"

Then, the definition of the differences across disciplines is rarely made in a structured and dialogic way. However, concretely expressing these differences in terms of vocabulary, research methods, tools, spatial and temporal scales, data, and guiding research rules and values, could significantly contribute to the recognition by scientists of a plurality of legitimate perspectives, to their understanding, and to the acceptation of their coexistence.

Finally, the equilibrium implied by the ‘management’ of these differences is fragile and not easy to reach. It demands from scientists that they start from what brings them together in a shared project, as convergences and similarities set benchmarks for interactions and help overcome the emotive feeling of ‘threat’; to then move towards what differentiates them, as divergences and disagreements are the starting point for acknowledging potential complementarities and launch authentic cooperations. This is not straightforward, as going too far down the route of differences might separate scientists. Our participatory action research showed how reflexivity facilitates the acrobatic performance of interdisciplinarity, by guiding scientists in their attempt to tame their points of divergence and recognise their complementarity.

2.2. Managing a changing identity while remaining authentic

Identity is a central issue to interdisciplinarity. Scientists of an interdisciplinary project bear their own personal and disciplinary identity. However, in interdisciplinary settings, this identity is not stable, but will be questioned, challenged, negotiated and built through the interactions; leading the scientists to have a different view on themselves and their discipline.

They must then perform an equilibrium exercise again, between being authentically involved in interdisciplinarity, and keeping an active role in their discipline. On one side, they must manage the distance created with their discipline, without jeopardising their disciplinary identity: How to remain up-to-date and efficient in the ‘home’ discipline, while devoting time to interdisciplinary projects? How to relate to disciplinary colleagues who think that “interdisciplinarity weakens disciplines” or that “interdisciplinarity is made for ‘bad’ researchers”? On the other side, scientists have to nurture their new ‘interdisciplinary’ identity, particularly by adopting attitudes such as openness, critical thinking, reflexivity or authenticity, that they have been experiencing through their interdisciplinary cooperations.

Beyond constituting a perilous balance, changing identity poses another, more overarching challenge when we consider that, at the same time, interdisciplinarity demands being authentic[10]. What, then, means to ‘remain authentic’ in a context of changing identity? We can differentiate between two levels. On one hand, a scientist remains authentic to his home discipline. It implies that he should not be afraid to share with his discipline his new identity, made of changed ontological, epistemological and methodological perspectives, and often characterised by increased cooperation, dialogue, and openness. However, proposing a critical scrutiny of the home discipline, even though it could encourage innovative research paths, might be an acrobatic step. Indeed, ‘interdisciplinary’ scientists have to ensure that they do not endanger their home discipline; with the potential threat of being rejected from it: “I am regularly seen by [my disciplinary colleagues] as a defector. For them, we have everything in our discipline, required to answer our issues”.

On the other hand, a scientist remains authentic to his interdisciplinary colleagues. Honesty and respect are expected regarding personal motivations, interests, representations and assumptions. Further, the scientist is invited to challenge, question, criticise, and debate the other disciplinary perspective, in order to find innovative research paths. Reflexivity, by enabling actors to better know themselves, contributes to this effort of authenticity, and thus helps managing the challenges of a changing identity.

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[10] Being authentic is taking the risk of revealing one’s true colours in the dialogue with others; it is daring to be oneself, and acknowledge one’s own imperfections and weaknesses. Beyond this honesty to oneself and to the others, authenticity demands the ability to scrutinise and challenge each other through dialogue. Being authentic thus allows for a diversity in the dialogue, as it is a way to share one’s own motivations, practices, or goals. From authentic interactions emerge new questions, new issues, new perspectives (Jollivet-Blanchard & Blanchard, 2004). In that way, authenticity is a fundamental dimension of interdisciplinarity.

2.3. Finding ways to cooperate while balancing power and freedom

This third challenge of interdisciplinarity demands that scientists working in interdisciplinary projects find a way to cooperate while balancing power relationships, characterised by asymmetry and dependence on one hand, and creative freedom on the other. Reaching this equilibrium presents two difficulties.

The first difficulty is to accept to cooperate in an asymmetrical setting. Indeed, many researchers and practitioners consider interdisciplinarity as a process where all actors involved have roles that are, at all times, equal or at least comparable. However, the actors of an interdisciplinary project (i) do not have the same role; (ii) do not work with the same intensity at the same time; and (iii) do not learn the same lessons from the process. The challenge is to accept this asymmetry of roles and contributions, of priorities, of work and participation rhythms, while ensuring that the different personal and disciplinary identities are recognised and respected.

Second, related to this challenge is an acceptance of loosing some independence in order to win more creative freedom. Indeed, committing to an interdisciplinary project implies to follow a specific agenda, set up by the group, to make compromises on the epistemological and methodological perspectives to be adopted, and to be responsible for the progress of the project. This might discourage researchers and practitioners who assume that interdisciplinarity is a way to achieve efficiency through the distribution of work tasks across a group. Our participatory action research with the HUMBOLDT scientists showed the temptation for disciplinary practices, perceived as ‘‘more easy, more efficient, self-governed and less time consuming’’, through, for instance, the organisation of the project along rather disciplinary ‘work packages’. The challenge is therefore to transfer the cooperative abilities used in a known, relatively safe, disciplinary context, to a context that is much less reassuring, where cooperation rules are built along the way, and where dependency to the others is synonym of innovation, openness, creation, personal expression and identity construction.

To face this challenge of balancing power and creative freedom, our action research has shown that reflexivity facilitates the acceptation of asymmetry and dependence, by realising that disciplinary practices do not offer more freedom in terms of actions, but rather locks individuals in particular schemes that limit the space for creation and innovation.

2.4. Navigating in complexity and uncertainty without getting lost

Interdisciplinarity is a trigger for diversity and innovation: it is based on the conjugation of various ontological, epistemological and methodological perspectives into combinations that give rise to scientific innovation. However, for scientists involved in interdisciplinary initiatives, this diversity can translate into fuzziness, confusion and complexity; with innovation perceived as a difficult and elusive attempt to navigate into uncertainty.

Indeed, in the absence of means of 'best practice' in the literature, scientists of interdisciplinary projects face challenging questions: Where to start from, in terms of human and scientific resources? For arriving where, in terms of social outputs and/or scientific results? And through which means, in terms of approaches, methods and tools? Moreover, practical questions are numerous, regarding the valorisation of the work or the communication methods. The danger, in absence of support, is that scientists become weary and disengage from the process. Therefore, as complexity and uncertainty are inherent to interdisciplinarity, the challenge is to accept these features, without getting lost.

To help scientists engaged in interdisciplinarity to accept this complexity and uncertainty, or at least navigate through them with more serenity, reflexivity, in our research, has supported the GIS CES scientists in their exploration and understanding of the multiple dimensions of their interdisciplinary project.

2.5. Being reflexive without being disillusioned

As sketched by our previous research within the GIS CES (Blanchard & Vanderlinden, 2010), and as we will explore further in Part 3, reflexivity seems to be a cornerstone of interdisciplinarity. It is reflexivity that advances the quality of interdisciplinarity, by encouraging questioning, dialogue and understanding by the scientists of what works and what does not work in their project.

However, reflexivity is a challenge in itself. First, reflexivity demands efforts, time, patience and perseverance. It is indeed not easy, and even less for those who are not familiar with this attitude, to make explicit one's own 'personal starting point and trajectory, social and religious belonging and adhesion, [...], disciplinary traditions and ways of seeing the world'[11] (Bourdieu, 2001). Second, being reflexive means facing one's own shortcomings, imperfections and weaknesses. It implies hence the acceptance by scientists involved in interdisciplinarity to be questioned and criticised, and, in turn, to be able to challenge, in a constructive and respectful way, the others' personal and disciplinary perspectives. Third, as reflexivity confronts one with their limits and with the complexity of interdisciplinarity, it can result in a paralysing effect. Flooding scientists with unstructured doubts and scrutiny can paralyse the progress of a project, or lead to disengagement and weariness.

[11] Translation from French by the author.

Hence, the challenge for scientists of interdisciplinary projects is to be reflexive without falling into disillusion. This is why, especially within interdisciplinary projects for climate change, which are often dominated by natural and 'hard' scientists not used to reflexivity, guidance is required; for instance through the model we propose in Part 3.

2.6. Learning and cooperating within efficiency-oriented institutions

Interdisciplinarity is a long-term process for two main reasons. First, it is a *learning process*, whereby scientists discover how to cooperate across and along their disciplinary differences. The complexity of interdisciplinarity, as well as its contextual nature, reinforce the need for scientists involved in interdisciplinary projects to dedicate time to this process. Second, interdisciplinarity runs on the long-term because it is a *cooperation process*. It thus implies a strong coherence and continuity, through which scientists can conjugate their disciplinary perspectives in an authentic way.

However, this exigence of time and continuity seems to be poorly adjusted to the current organisation of research, characterised by short-term projects and seeking foremost results, efficiency and prestige. Such a framework does not seem flexible enough for reflexive interdisciplinary research. Scientists involved in interdisciplinarity face the overarching challenge of facing institutions with conflicting agendas and expectations. How to satisfy the expectation of scientific efficiency when engaged in a process that requires time to build familiarity, and does not give immediate results?

There is no simple answer to this, as the foundation of the current shape and nature of science is put into question by interdisciplinarity. Indeed, the quality of a research inquiry depends in part on the resources and time allocated to it. Hence, if the timeframe of a project aiming at working on a complex topic is two or three years, then what happens to the quality of the research? Complex, real-world problems such as climate change do not fit a single discipline, neither do they seem to fit research projects. For these problems, a long-term research endeavour, fostering participation, flexibility and reflexivity, appears to be more suited.

3. A model of reflexive interdisciplinarity for climate change: contributions and challenges

Based on the six challenges that arose from our participatory action research, we asserted that scientists involved in interdisciplinarity would benefit from a 'guided' step of long-term reflexivity, in order to implement authentic cooperations capable of delivering innovative results. By 'guided', we mean that a structured and reciprocal dialogue between what Snow (1998) calls the 'two cultures', in this case between STS scholars and climate-related scientists, is necessary, as reflexivity is a long-term learning process especially for actors who are not familiar with it. Framing this reflexive step as dialogue is important for two reasons. First, it allow the STS scholars to not *impose* reflexivity as the best solution, but help them to better understand the reality of climate-related scientists, in order to rather co-construct an array of approaches for dealing with complex issues. And second, if climate-scientists wish to commit to reflexivity, it allows them to not get lost along the meandering and sometimes isolating route. For instance, in our participatory action research, the STS scholars had the role of bringing the first elements of theory on reflexivity and design tools to facilitate reflexive dialogue, while climate-related scientists were expected to scrutinise the tools and make propositions for improvement according to their context. We believe that the more participatory the construction of the tools is, the more involved both communities will be, and the more relevant the tools will be.

We therefore propose a model of reflexive interdisciplinarity for climate change, that could be appropriated for other interdisciplinary initiatives. In our model, this dialogue takes the shape of action-reflection cycles where the STS and climate communities mutually nurture their understanding of reflexivity and participate to its implementation. Reflexivity concerns three levels: the method to implement interdisciplinarity, the scientist himself, and the disciplinary assumptions; and is supported by four reflexive tools: inaugural contracts, writing pauses, summary tables and harmonised presentations; which, we will see, mutually support and reinforce each other.

3.1. Inaugural contract in the incubation phase

The early interactions between scientists of a common interdisciplinary project are fundamental as they will steer the orientation of the project, in terms of objectives, means, and degree of authenticity within the project. Moreover, it is at this early stage that the risk is greater for scientists to disengage from the project, as they are not completely committed to it yet. Indeed, they can either be surprised and afraid of the complexity and uncertainty inherent to interdisciplinarity; or feel that their own perspective is not sufficiently taken into account.

To avoid disengagement, or locking the project up in strategic behaviour to avoid the complexity and uncertainty of interdisciplinarity (for instance, by splitting the work in disciplinary tasks), we propose an inaugural contract as a reflexive tool formalised in the field of educational sciences by Jollivet-Blanchard & Blanchard (2004). Taking place in the incubation phase (see Part 1.1.), this tool, symbolically signed by both the climate-related scientists and action researchers, allows them to collaboratively define (i) the role of each member of the project, (ii) the objectives and means of this project, and (iii) the values or rules of interaction (see Appendix A for an extract of HUMBOLDT's inaugural contract).

These features of the inaugural contract help scientists both in their reflexive and interdisciplinary endeavour. First, collectively discussing and formalising the role of each discipline and scientist helps them realise and acknowledge their belonging to a group; on one hand, they are responsible of its progresses, and on the other hand, it is only through the interactions with this group that they will achieve meaning on a complex issue. In this way, the inaugural contract facilitates the acceptance of asymmetry and dependence, by realising that scientists have different roles, at different times of the project.

Second, collective and reflexive deliberations on the set of objectives helps actors to serenely navigate in the complexity and uncertainty of interdisciplinarity, by having some benchmarks indicating their direction. The agenda, however, should remain flexible enough to allocate time and space for unexpected results or mechanisms. Furthermore, discussing the means to implement encourage scientists to reflexively think about how different assumptions on the nature of knowledge and the way to access it may lead them to support a certain perspective, and set others aside: "You [biologists] are used to work at small spatial scales, and model precise processes; but your aspiration for a 1 km scale is an unrealistic fantasy for us [climatologists] who see the world from a much larger scale".

Third, collectively clarifying the values of interactions facilitates the disclosure of each participant and gives rise to authentic relations in a secure atmosphere. In our participatory action research, scientists recognised their duty of critique, while respecting the legitimacy of a plurality of disciplinary perspectives: “In this meeting, we all acknowledged the importance of being respectful and honest: it is better for the project that we enter into true, sometimes bitter discussions, so that we can get into the thick of things”.

However, the inaugural contract may be misused, in the sense that it may encourage a search for the single ‘best’ epistemological and methodological perspective. In order for the inaugural contract to support reflexive deliberations over the ways to articulate the different disciplinary perspectives, the contributions and complementarity of the latter, even though unequal, should be emphasised and reminded.

3.2. Harmonised presentations

Harmonised presentations mean that all scientists or disciplines of an interdisciplinary project present to the group using a uniform or standardised format. For instance, when using electronic slides, they will be organised around the same structure and headings (see Appendix B). Harmonised presentations, as reflexive tools, can either be used at the beginning or later in the project.

If they are used at the beginning of the project, during the incubation phase for instance, then they allow the various disciplines to introduce themselves in a reflexive and structured way. Disciplines can be required, for instance, to reflect on and share (i) their motivations for committing to the project, in order for their interests to be collectively discussed; (ii) their perspective on the issue, or how they frame it according to their disciplinary perspective; (iii) their contributions to the issue, by presenting approaches, tools and data that might be useful to its understanding; and (iv) their limits in the understanding of the issue, by expressing what they expect from the other disciplines. This step appears to foster recognition and a greater acceptance of asymmetry and dependence: "These harmonised presentations made me realise that we all have different approaches of the same object. Our interactions will be incredibly rich and fruitful!"

If the harmonised presentations are used later in the project, they allow scientists to more specifically reflect on and discuss the various disciplinary perspectives on a particular aspect of the cross-issue. This is a way to ensure that decisions in the project are taken according to the collective endeavour to navigate in the complexity of interdisciplinarity.

3.3. Summary tables

To further support the scientists' endeavour for interdisciplinarity and reflexivity, we believe it is important for them to individually take the time, through writing, to understand the other disciplines' ontological, epistemological and methodological assumptions, and reflexively take distance on their own disciplinary presuppositions.

To this aim, we propose summary tables that can be used in combination with the inaugural contract and/or during harmonised presentations. They are constituted of empty tables, individually given to each scientist of the project, in order to help them to explore in a structured and reflexive way the other disciplines according to, for instance, their approaches, values or ethical rules, tools, data, spatial and temporal scales (see Appendix C). To help scientists further understanding the other disciplines, summary tables allow a direct comparison between these disciplines and the 'home' discipline. Summary tables, as reflexive tools, help scientists face the challenges of interdisciplinarity in two ways.

First, when the individual contributions or tables are put together in a common summary table, convergences and divergences between the disciplines of a project are directly highlighted; thus constituting a basis for reflexive discussions on how to conjugate these disciplinary perspectives in order to best answer the cross-problematic. These tables allow increased recognition of the incompleteness of each disciplinary approach to achieve meaning on the problematic, and scientists seem to better accept the potential asymmetry of roles between the disciplines involved: "Through these crossings I realise now how pretentious it was of me to think that the other disciplines would bring side contributions only!"

Second, putting together and comparing the individual tables allows to emphasise how each scientist: (i) reflexively sees his own discipline; (ii) sees the other disciplines; and thus highlights (iii) misunderstanding on each other's discipline. It is important to explain and debate these misunderstandings before engaging the future steps of the project.

3.4. Writing pauses

Finally, writing pauses, like summary tables, encourage individual written reflexivity, similar to a diary. They consist in small booklets with, on the top of each page, an open question (see Appendix D). These pauses are used during collective meetings, in order to allow time for introspection and personal reflection on the interdisciplinary project. More particularly, scientists are encouraged to: (i) question their interests for and representations of interdisciplinarity, as well as their motivations for participating to the project; (ii) take distance on their ontological, epistemological and methodological assumptions, and evaluate how these assumptions could contribute to, or impede, the project; and (iii) express their feelings and share their observations and propositions regarding the project. Beyond an increased recognition of the legitimacy of the other personal and disciplinary perspectives, writing pauses, as reflexive tools, present two main contributions to face the challenges of interdisciplinarity.

First, they allow scientists of an interdisciplinary project to be reflexive and authentic, and express themselves outside the hierarchical or power constrains and influences of the group. Writing pauses thus encourage personal reflection, structured according to personal priorities and representations. For the more introverted, this indirect way facilitates the expression of authentic critiques that are thereafter mobilised anonymously in the discussions. These authentic inputs facilitate the dissolution of important misunderstandings: "As a biologist, I entered in this project thinking that we would have the leading role. I must say, I was first surprised to see it was not the case. But now I understand that urban greenways are far from being merely a biological object: we really need the social and climatic perspectives".

Second, writing pauses support navigation in the complexity and uncertainty inherent to interdisciplinarity. Through writing pauses, scientists are able to explore and structure the diversity of ideas that had emerged from the interactions. Individually first, and then collectively, ideas and knowledge are stabilised in what we could describe as reflexive and evolving platforms, supporting the following interdisciplinary interactions.

3.5. The mutual influences of the four reflexive tools

As it has been shown through the description of our four reflexive tools, *individual, written reflexivity*, encouraged by writing pauses and summary tables; and *oral reflexivity in interaction*, supported by the inaugural contract and harmonised presentations, mutually influence and reinforce themselves.

Individual, written reflexivity first encourages the recognition of the plurality of legitimate perspectives, by reflecting upon the rules, methods and practices along which knowledge is produced within each discipline. This helps scientists of an interdisciplinary project to reflexively scrutinise their discipline, and realise the need of conjugating various disciplinary approaches to achieve meaning on their cross-problematic. Second, individual reflexivity gives time and space to the scientists to better accept the complexity and uncertainty inherent to interdisciplinarity, by exploring and structuring it according to their references, ideas and priorities.

After these individual, written reflections, actors of interdisciplinarity appear to be more sensitive to the presence of other valuable ontologies, epistemologies and methodologies. In this way, individual reflexivity prepares for respectful and authentic oral interactions, as scientists realise their responsibility towards the progresses of the project. This open and authentic atmosphere encourages reflexivity in interaction, which, in turn, supports a deeper self-scrutiny of one's own assumptions and motivations.

The intertwined, reinforcing influences of individual, written reflexivity, and oral reflexivity in interaction seems to concretely give effect to more participatory and flexible decision-making, allowing for adjustments to the trajectory of a project in terms of objectives, means and structure with, as a result, a more coherent, innovative, and authentically interdisciplinary project.

3.6. Some future challenges

This model of reflexive interdisciplinarity, fostering dialogue between STS scholars and climate-related scientists, faces two important challenges. The first challenge is to ensure that this dialogue *is* reciprocal and authentic. The concern is that STS does not impose norms of reflexivity on climate

-related scientists as something that is ‘good for them’, reminiscent of a deficit model. Indeed, we can reasonably call into question the ‘goodness’ of reflexivity for *all* situations, considering that reflexivity taken to its provocative extreme could lead to the nihilistic collapse of natural science projects. It is for this reason that we advocate a form of reflexivity that emerges from dialogue that recognises the co-existence of the ‘two cultures’ and allows for their co-construction of the concept. That is, a reflexive process that is of mutual agreement to both groups.

The second challenge faced by our proposed model for reflexive interdisciplinarity is that, reflexivity, like interdisciplinarity, is a long-term learning process. The adoption of reflexive attitudes takes time, especially around the issues of climate change where there is still a majority of natural and ‘hard’ scientists not familiar with this process. However, a recurring tension is between nurturing long-terms norms of reflexivity and interdisciplinarity within short-term projects, which are often defined according to a isolated set of outputs, with little or no attempt for continuity. Hence, the model presented faces limits of scope; while it might be useful or efficient on the short-term, the usual length of current research projects, two or three years, may preclude the effective integration of reflexivity into research habits.

Conclusion

Interdisciplinarity is a challenging, long-term process. Scientists involved in interdisciplinarity for climate change face six challenges, non-negligibly demanding of them to be cooperative, authentic, open, hetero-centred, adaptive, and critical. Reflexivity, we asserted in this paper, when it is guided by a structured reciprocal dialogue between STS scholars and climate-related scientists, and supported by specific tools, seems to facilitate the expression of these research attitudes. We hence proposed a model of reflexive interdisciplinarity for climate change based on four reflexive tools, in order to provide scientists with some benchmarks from which to start reflexive discussions on how to best implement interdisciplinarity for their particular issue or project.

This model, however, is far from being perfect. It is very context-based and non-exhaustive in the range of tools proposed. Foremost among the limits, it promotes reflexivity as a long-term learning process, which conflicts with the current organisation of scientific research mostly based on efficiency, evaluation, and prestige. Nevertheless, we encourage STS scholars and climate-related scientists of future interdisciplinary projects, with this paper as a starting point, to continue this dialogue across their 'two cultures', as it has shown promising outputs in terms of collectively defining what it means to be interdisciplinary.

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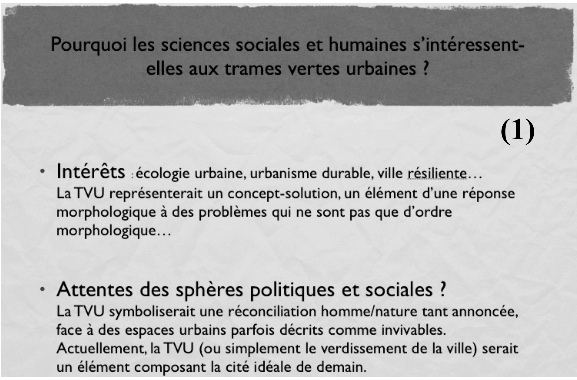
Appendices

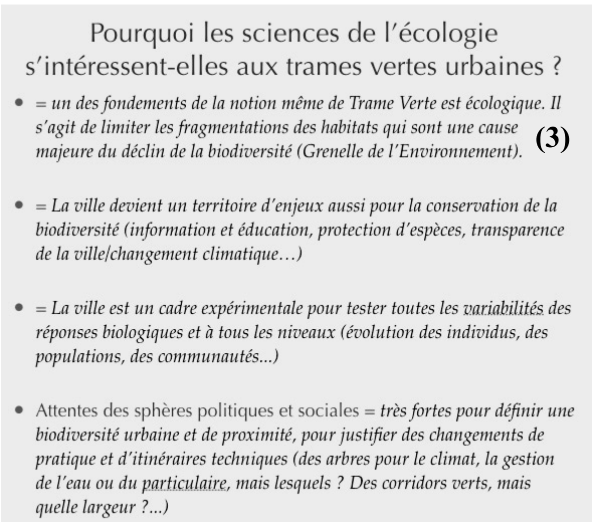
Appendix A: Extract of inaugural contract

Extract of HUMBOLDT's inaugural contract		
Roles of the project members	'Biology' community	✓ Modelling biodiversity in link with climate change ✓ Communicating results to decision-makers ✓ Giving feedback to the action researchers ✓ ...
	'Climate' community	✓ Modelling climate change in link with biodiversity ✓ Finding relevant climatic databases ✓ Giving feedback to the action researchers ✓ ...
	Action researchers	✓ Understanding the context of climate-related scientists ✓ Facilitating the process of interdisciplinarity ✓ Bringing new perspectives / designing new tools ✓ ...
Objectives and means of the project	Substantive	✓ Increasing the amount of scientific knowledge around the issue 'biodiversity and climate change' ✓ Creating new models ✓ ...
	Procedural	✓ Better understand how interdisciplinarity works ✓ Increase the level of interaction among various scientific disciplines ✓ ...
	Contextual	✓ Better understand science in its wider context (what means 'science in society'?) ✓ ...
Values of interaction	✓ Recognition ✓ Honesty ✓ Authenticity	✓ Critical reflection ✓ Flexibility ✓ ...

***Note**: The contract was in reality more complex; with, for instance, the roles being detailed according to each scientist and reaching thus an increased variety.*

Appendix B: Extract of harmonised presentations





These three extracts, in French, originate from presentations during the CCTV project's launch meeting. More particularly, these three slides show the answers of (1) social and human sciences, (2) climate sciences, and (3) ecology to the question: 'Why is [your discipline] interested in urban greenways?'

The three disciplines used the same electronic slide-show format, with however colour codes for a better differentiation of the three groups of disciplines.

Appendix C: Extract of summary tables

Extract of summary tables used during the CCTV project, during the harmonised presentations			
DISCIPLINARY CHARACTERISTICS	**Climate sciences**	**Ecology**	**Social and human sciences**
Approaches	Chemistry, physics Measures, observation, modelling, scenarios ...	Geography, geology, biology, physics, etc. Observations, measures, identification, descriptions, modelling ...	Semantic approach. Study of past events, representations, socio-political systems. ...
Tools	Models Simulations Informatics GIS ...	GIS Experiments Models Maps ...	Interviews Analysis softwares Literature Observation ...
Values or ethical rules	Rigour Precaution Explanations Protection ...	Aesthetics Ecology Co-construction Respect for life ...	Participation Democracy Reflexivity Social relevance ...
Data	Quantifiable data from models or observation Data on climate, temperatures, energy ...	Quantitative data from models or observation Data on species, ecosystems ...	Qualitative data from archives or fieldwork. Measures of health, welfare ...
Spatial scales	Very variable: from micro to Earth	All scales	Rather local, linked to individuals
Temporal scales	Very variable: instant, season, decades, century ...	10 to 100 years ...	Instantaneous to human history ...
...	...	...	...

Note*: The summary tables of CCTV were in reality more exhaustive. Furthermore, in each cell, the difference was made between what a discipline would say on itself, and the perception / interpretation of the other disciplines relative to this.*

Appendix D: Extract of writing pauses

First focus group

1. What are your expectations towards this first focus group? And towards the other disciplines?
2. What do you think you and your discipline could bring to the HUMBOLDT project?
3. After this first phase of discussion, do you perceive convergences between the various disciplinary approaches?
4. Do you perceive challenges to interdisciplinary dynamics across these disciplines? At which level(s)?
5. How do you think these difficulties could be solved?
6. Is there any other remarks, observations, suggestions you would like to make?
7. What do you think of the support of the [action researchers]?

Second focus group

1. According to you, are the language issues within the disciplines involved in HUMBOLDT solved today?
2. According to you, are the scales issues within the disciplines involved in HUMBOLDT solved today?
3. According to you, are the tools issues within the disciplines involved in HUMBOLDT solved today?
4. According to you, are the approaches issues within the disciplines involved in HUMBOLDT solved today?
5. If no, what do you think is their origin(s)? And how do you think they could be solved?
6. Is there any other remarks, observations, suggestions you would like to make?

These writing pauses were led during the two HUMBOLDT focus groups, to allow participants to take distance on their project and propose personal remarks, observations and suggestions. Here, the questions are squeezed one after the others, but in reality, a whole page was left free for the written answers of the scientists.

Paper 4

Anne Blanchard

Invitation to reflexive dialogue on the science-policy interface for climate change

Under submission

IV

Invitation to reflexive dialogue on the science-policy interface for climate change

Anne Blanchard

Abstract

Much has been written in the social sciences, and Science and Technology Studies (STS) in particular, on the way knowledge is mobilised in support of decision-making across the science-policy interface; not least for climate change. But to what degree is the discourse in the literature congruent with the experiences and self-understanding of those actors actually active at the science-policy interface? This paper presents a participatory action research that initiated reflexive dialogue between climate-related scientists and STS researchers, around a particular interdisciplinary project on climate change. It seeks to simultaneously interrogate the theory relative to current practice at the interface, and interrogate practice relative to the literature. The research identifies interesting points of convergence and divergence between some key debates from the literature and how they presented themselves in practice. Perhaps most notably, we saw that the two groups of STS scholars and climate-related scientists started from quite different ontological and epistemological representations of climate change, with clear implications for their discussion of the science-policy interface. The paper concludes by emphasising the importance of reflexivity and invites scientists from the 'natural' climate-related sciences to engage in such dialogue in the interests of theory and practice.

Keywords: Science-policy interface, reflexivity, dialogue between STS and climate communities, climate change.

Introduction

In the large and growing literature on climate change within the social sciences in general, and Science and Technology Studies (STS) in particular, the science-policy interface is one of the main topics of debate. This rich literature on the science-policy interface offers both descriptive (see e.g., Jasanoff (1987) and Shackley et al. (1998)) and normative stances (Eden (2011)), with its multifarious debates unfolding both within scholarly publications and more practical circles (Bussereau, et al., 2004). What this literature shares is a common focus on those actors active within the science-policy interface, such as climate scientists or policy-makers, to understand how they perceive themselves and their actions relative to others. Given that both (natural) climate scientists and the STS researchers studying them all take part in the science-policy interface, it is relevant to ask about the relationship between this 'STS scholarship' and the self-understanding of the actors studied; is there congruence between what is asserted in the literature and what is experienced by actors? If not, why?

In this paper, we present empirical material that explores how a group of climate-related scientists perceive their own position and role at the science-policy interface and how they envisage the potential improvement of this interface. This study followed the interdisciplinary 'HUMBOLDT project', a research project on the relationship between climate change and biodiversity in the French Alps, carried out by the Scientific Consortium for Climate, Environment and Society in Paris. Through participatory action research, we nurtured a critical reflection amongst the scientists on the science-policy interface. We found that while many of their reflections had a degree of correspondence with debates in the literature, there were nonetheless some important divergences. This led us to reflect upon the relationship between our STS perspective on climate change and the science-policy interface on one hand, and the HUMBOLDT scientists' perspective on the other; that is, to interrogate the literature relative to practice, while interrogating practice relative to the literature.

The critical reflection in this paper unpacks the HUMBOLDT scientists' perspective on the science-policy interface relative to some key debates from the literature. It takes as its 'point of departure' an increasingly common understanding among STS scholars of climate change as complex and uncertain; asking climate-related scientists: Is climate simple? Is climate knowable? Is climate controllable? It moves on to engage three more contentious debates framed as three coarse but didactically useful dichotomies:

(i) Debates between those authors describing how the science-policy interface *is*, as a 'messy' social and political process, and those authors prescribing how it *ought to be*, in terms of scientific best practice;

(ii) Debates on communication at the science-policy interface, between authors explicitly advocating or implicitly assuming a public deficit model and those who favour symmetric dialogue;

(iii) Debates on the treatment of non-scientific knowledge, between those authors who seek its reconciliation within scientific frameworks, and those who allow knowledge systems to coexist.

The paper is articulated around four parts. Part 1 presents the HUMBOLDT project and our participatory action research. Part 2 is concerned with HUMBOLDT's perception of climate change, and compares it to that found in the STS literature. Part 3 compares HUMBOLDT scientists' perspective on the science-policy interface relative to three ongoing debates of the STS literature. And finally, in Part 4, the paper discusses the key findings that emerged from the critical reflection, and the implications of divergences between scholarship and practice. The findings of this critical reflection indicate that there is a need for increased dialogue and reflexivity between STS scholars and climate-related scientists. The danger is, however, that by asserting the need for norms of dialogue and reflexivity, STS researchers themselves fall into the trap of dictating best practice via a deficit model; the very model a dialogic approach is supposed to avoid.

1. Qualitative research and methodology

1.1. Participatory action research to foster dialogue and reflexivity

The results presented in this paper originate from a six-month participatory action research study led by two scholars[1] in Science and Technology Studies (STS) in 2010, within the Parisian Scientific Consortium for Climate, Environment and Society (GIS CES)[2]. A participatory action research approach was chosen to encourage dialogue and reflexivity through cycles of individual and collective reflections and actions (Reason & Bradbury, 2006; Stringer, 2007). Our objective was to implement a reciprocal and iterative dialogue between us, STS scholars, and climate-related scientists, with critical reflections on the science-policy interface. The study involved ten volunteer

[1] Anne Blanchard (author of this paper) and Prof. Jean-Paul Vanderlinden.

[2] The acronym GIS CES comes from the French title: 'Groupement d'Intérêt Scientifique pour le Climat, l'Environnement et la Société'. This Consortium is in charge of (i) funding and supporting interdisciplinary research projects concerned with the impacts of climate change on social, economic and environmental spheres; and (ii) facilitating the mobilisation of interdisciplinary climate-related knowledge for decision-making. For further informations, see our previous publications based on qualitative research within the GIS CES (Blanchard & Vanderlinden, 2011, forthcoming), and the website http://www.gisclimat.fr/en

scientists[3] from the interdisciplinary and policy-oriented HUMBOLDT project[4]. HUMBOLDT was funded by the GIS CES in 2009, for a period of three years. Its objectives first consist in the interdisciplinary understanding and modelling of the links between climate change and the evolution of biodiversity in the French Alpine region, by bringing together two broad scientific 'communities': climate scientists and biologists. Secondly, HUMBOLDT tries to elaborate 'biodiversity indicators' of the impacts of climate variability on biodiversity to be used in environmental management.

The study involved five major steps: (1) a launch meeting, where the objectives and agenda of the interactions between the HUMBOLDT scientists and action researchers were cooperatively formalised and agreed-upon; (2) a first set of 9 semi-structured interviews on how the scientists represent climate change and build knowledge on it; (3) a first focus group discussing the role and responsibility of scientists at the science-policy interface for climate change, and the challenges of this interface; (4) a second set of six semi-structured interviews on scientists' vision of political action for climate change; and (5) a second focus group, centred rather on internal aspects of scientific collaboration not relevant for this paper.

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[3] Of over 50 persons broadly taking part to the HUMBOLDT project, 10 scientists free-willingly agreed to participate in our participatory action research. From now on in this paper, when we talk about 'the HUMBOLDT scientists', we will specifically refer to these 10 volunteer scientists.

[4] Human Impacts on Biodiversity, Ocean Environment and Climate in the Anthropocene (HUMBOLDT). Project funded by the GIS, for the period 2009 - 2012. For further informations, see the website http://www.gisclimat.fr/en/project/humboldt

1.2. Data analysis

a) Semi-directed interviews

The two sets of semi-directed interviews were analysed by 'thematic analysis'. These interviews, of 30 minutes to one hour each, were recorded and transcribed, and transcripts were then classified according to main categories. Examples of categories from the first set of interviews are: 'objectives of your discipline', 'ways of producing knowledge' or 'your representation of climate'. Under each category arose sub-categories, refining the data with more detail. For instance, sub-categories for the category 'objectives of your discipline' were labelled 'reproduce reality', 'anticipate / predict', 'quantify uncertainties', or 'make results useful for decision-makers'. The interviews were read several times in order to validate the regular use of the sub-categories and their completeness.

From the first set of interviews, it became clear that there were some significant points of divergence and convergence between how the social science literature depicts the science-policy interface setting, and how climate-related scientists represent their role in it (see Parts 2 and 3). These divergent perspectives on the science-policy interface were unpacked and explored further with the HUMBOLDT scientists through the first focus group, and second set of interviews.

b) Focus groups

Two focus groups of two hours each were run in order to investigate the HUMBOLDT scientists' representations and perspectives through their interaction (Morgan, 1993). Only the first focus group, concerned with the science-policy interface for climate change, is included in this paper. Six HUMBOLDT scientists participated in this focus group, to discuss the role and responsibility of scientists as one group of actors at the science-policy interface for climate change. The issues or aspects tackled in the focus group were submitted to a thematic analysis. As for the interviews, we first classified the 'raw' statements under broad categories reflecting the open-ended questions asked during the focus group: 'objectives of HUMBOLDT', 'role and responsibility of scientists in a context of climate change', and 'scientists and decision-makers'. We organised these into more detailed sub-categories such as, for the broad category 'scientists and decision-makers': 'divergent interests', 'cultural distrust towards science', or 'challenge of communicating around uncertainties'.

The discussions around the science-policy interface during the focus group were very lively, translating a tension among or indeed within participants, between the wish of responding to socio-political needs and the need to keep scientific integrity and quality. This idea is developed in Part 3.

2. Divergent framings of climate change across social and climate sciences

If we accept that the science-policy interface is part of society's response to climate change, then it follows that the way we represent this issue has a significant bearing on the shape of the science-policy interface. The framing of climate change can therefore be considered the point of departure for instituting a science-policy interface. As such, it was with significant interest that we found very divergent representations of climate and climate change between the STS literature and the HUMBOLDT scientists. This is important because it shows that, in discussing the science-policy interface, STS and climate-related scientists may be beginning from very different points of departure.

2.1. Is climate simple?

In the STS literature concerned with the science-policy interface, the complexity of socio-ecological systems is emphasised: ‘‘Climate [...] will likely always be complex: determinism in the midst of chaos, unpredictability in the midst of understanding’’ (Rind, 1999). More particularly, climate change is often referred to as a ‘wicked problem’ (Rittel & Weber, 1973), or characterised by Funtowicz and Ravetz’s (1993) ‘post-normal’ features: uncertainty, plurality and contentiousness. In recognition of the complexity of climate change, STS scholars question the validity of its representation through linear and mechanistic methods, such as the ‘general circulation models’ (Shackley, et al., 1998), and propose embracing, rather than avoiding, the complexity and diversity inherent to this issue (Rounsevell & Arneth, 2011). Indeed, for many, the best way for society to face climate change is to represent it as complex, and design similarly complex social responses, with Duit et al. (2010) for instance referring to the ‘diversity hypothesis’ according to which ‘‘institutional and organisational diversity is the most effective way to cope with complexity’’.

In our empirical material there is much less emphasis on the complexity of the climate. While acknowledging the ‘‘interconnected implications that concern all scales, all countries, and all the aspects of society’’, the HUMBOLDT scientists generally asserted that by decomposing the climate into its constituent parts and simplifying its processes, they may reduce the complexity and understand the climate: ‘‘through mechanist modelling, we try to understand each process, each connection, each component of climate; if we understand them all, then we can start making predictions’’. In this way, climate-related science was seen as an exact science by the scientists; who talked numerically in terms of concrete thresholds and effects: ‘‘Biodiversity is very sensitive to climatic conditions. [...] Between 35 and 38°C, photosynthesis goes from its maximum level of activity to zero; so if the models are 2 or 3°C wrong, it is a very important error''.

In sum, the interviewed scientists did represent climate and its changes as complex, but did not subscribe to the belief that this complexity is irreducible; marking this as an important ontological divergence with the STS literature.

2.2. Is climate knowable?

When talking about the epistemological access to climate, the STS literature frequently puts forward the uncertain, evolving, non-linear and emergent properties of the climate that render its comprehensive understanding and prediction impossible: ''Questions concerning the future climate will probably continue to be dominated by uncertainties'' (Rind, 1999). Millner (2011) questions the utility of climate predictions since 'epistemological uncertainties' will always remain: ''the constraints on the accuracy of long-term predictions [pose] intrinsic structural limitations to the utility of long-term predictions for adaptive decision making''. This leads many STS authors to propose, a recognition and acceptance of irreducible uncertainty. Jasanoff (2003) advocated 'technologies of humility', in order to ''systematically [assess] the unknown and the uncertain''. van der Sluijs (2007; 1997) has proposed a 'post-normal' approach to the issue, where knowledge is appraised according to standards of 'quality' for decision-making rather than 'truth'.

We got a quite different answer from our informants-participants climate-related scientists to the question 'is climate knowable?'. They expressed the belief that the climate and its changes are knowable and that it is their precise mission to build knowledge around this issue. The scientists described their role as understanding and reproducing reality, in order to predict the future: ''our disciplines are based on a triad: observation, modelling, and theorisation'', with these models and theories validated against observations of 'reality'. However, this validation step is complicated due to the global nature of climate change: ''it poses a challenge at the large scale, because direct observations are not available''. In response, the HUMBOLDT project adopted interdisciplinary practices, as a means of cross-validation across disciplines. Interdisciplinarity was indeed intended to act both as a means to validate (according to the standards of science only) scientific results in a context of uncertainty and complexity, and as a way to achieve more comprehensive knowledge: ''by assembling models from different disciplines, we might find ways to enhance them; our interactions will allow us to better frame climate-related uncertainties and thus increase our scientific robustness''. Finally, in the scientists' point of view, uncertainties do exist but they can be quantified and reduced through ''robust'' science, allowing ''improved predictability'': ''by crossing our expertise, we will reach very small spatial scales, like we never did before''.

In simplified terms, in contrast to notions of epistemological uncertainty, climate-related scientists commit to the idea of a knowable climate, with knowledge gradually expanding and accumulating, and uncertainties being framed and reduced: ''through HUMBOLDT, we want to produce more knowledge on the interactions between ecosystems and climate, and better frame the uncertainties of our models''.

2.3. Is climate controllable?

Over the last two decades, the STS literature has substantially expanded on the questions of governance for complexity. Endorsing the uncertain, complex and therefore uncontrollable nature of climate and its changes, many authors (Grunwald, 2008; Nowotny, Scott, & Gibbons, 2001; Pellizzoni, 2011; van der Sluijs, 1997; Wardekker, van der Sluijs, Janssen, Kloprogge, & Petersen,

2008) underline the demanding challenges that this issue poses to current societies, in terms of how and when to act: ‘‘First, time-lags between human action and environmental effect are very long, often extending beyond one human generation. Second, problems are embedded in highly complex systems that are not well understood. Third, these problems involve global collective goods of a type that links them to a wide range of human activities and leaves them beyond the scope of unilateral solutions’’ (Underdal, 2010). Against this background, many STS scholars reiterate the need to accept the uncontrollability and unpredictability of climate change; with, for instance, Duit et al. (2010) advocating for new models of governance that balance change and stability: ‘‘flexibility is needed to adapt to novel and unexpected circumstances, but stability is of equal importance for ensuring that governance systems retain their ability to regulate behaviour and provide a predictable arena for interaction between actors’’.

As reported above, our informants-participants did not fully commit to the idea of an uncontrollable climate. While acknowledging its uncertainties, the HUMBOLDT scientists described climate change as ‘‘rather predictable’’ and therefore ‘‘controllable to a fair extent’’. They claimed being able to provide decision-makers with ‘‘a precise idea of what to do’’, a ‘‘one-stop shop where they can go and get information, and be relatively sure that this information is what they need’’. While uncertainties may make scientists cautious, they are no excuse for inaction, as they can be precisely framed and quantified, thus controlled, and explained to decision-makers. For the HUMBOLDT scientists, a fundamental aspect to action for climate change is a ‘‘sound scientific understanding of how climate and atmospheric change will modify biodiversity so that policy makers can be appropriately alerted to the possible effects of global change on biodiversity, natural resource management strategies can be adapted to account for climate change, and assessments can be made of the potential effects of climate related changes in biodiversity on ecosystem services’’. In this way, assessments of potential impacts of climate change allow the building of management strategies to shape the future trajectory of society and the climate.

In simplified terms, while STS scientists underline the uncontrollable and unpredictable nature of climate, climate-related scientists assert that linear ways of control (notably through models) are sufficient to take actions. Pellizzoni (2011) explains these divergent perspectives in terms of a different ‘‘understanding of the ontological quality of the biophysical world. The latter is conceived [by climate-related sciences] as fully plastic, controllable, open to an ever-expanding human agency’’.

3. Three ongoing debates on the science-policy interface for climate change

As has been noted, the literature on the science-policy interface for climate change is vast and multifaceted. It can be seen from many different perspectives, like turning a kaleidoscope, to reveal different debates and patterns. This part goes on to look at three important issues of debate from the literature, framed as coarse but didactically interesting dichotomies. These issues are of course not independent; indeed they overlap. The goal here by framing these issues is to simultaneously interrogate the practice of the HUMBOLDT scientists relative to important considerations in the literature, while interrogating the representations in the literature relative to the realities of the scientists.

3.1. The science-policy interface as 'science speaking truth to power' or as 'boundary work'?

Within the STS literature treatment of the science-policy interface for climate change, we can distinguish a broad dichotomy. On one hand, there is a community of authors who see science as the source of rationality, and address the challenges of how to connect science to decision-making in terms of allowing 'Truth to speak to Power'; while on the other hand there are authors who study knowledge as socially constructed, with its mobilisation across the interface equally a process of social and political negotiation.

As to the former tradition, we see literature on how best to mobilise 'useable science' in a form able to provide tangible support to decision-makers. Eden (2011) for instance discusses fundamental strategies of useable science for climate change, including reconciling the advancement of science with providing decision support, fostering the adoption of scientific products, and communicating science with policy-makers. In this way, much of this literature begins from a strong normative assumption that science *ought to* be the basis for rational decision-making and seeks means to 'close the gap' between the two. For example, Jakob et al. (2011) discuss models that link climatic and economic systems, in order to analyse the economic 'cost' of climate change and hence make decisions as 'rational economic actors'.

As to the latter tradition, we see a number of scholars attempting to describe and make sense of the complex social and political interactions that for them characterises the science-policy interface (see e.g., Gieryn (1999) and Guston (2001)). Such 'sociological' understandings of knowledge thus focus on how knowledge *is* mobilised, within the contested 'boundary' between two distinct communities. As Jasanoff (1987) notes: 'the lines between science and policy are difficult to draw, not merely because science is indeterminate, but because the effort to make such distinctions is politically charged'. As such, authors within this tradition are concerned with studying the actors that choose to work at the boundary, their motivations and preconceptions, and the way they interact. These scholars ask why certain forms of knowledge become perceived as more salient, legitimate, and credible than others. Discussions on 'boundary work' thus begin from notions of how scientific and policy communities interact to co-construct the reality that informs society's decisions, and the power that shapes these interactions.

In our study, the climate-related scientists mostly endorsed the first-mentioned line of thought. They believe in the perfection and perfectibility of their knowledge, the validity and robustness of which is, in their words, achieved through objectivity, pragmatism, rigour, and intellectual honesty. They thus consider science as the best knowledge for supporting decision-making. It follows then that their concern, when talking about the science-policy interface for climate change, is how best to link their science to decision-making.

Across the interviews, the scientists made three propositions for connecting science with decisions and action. First, the HUMBOLDT project itself aims at creating linked climatic and biodiversity models in order to "provide decision-makers with data to better govern climatic risks and draw pertinent adaptation policies. [...] We will [...] provide assistance with the understanding and use of the projections". Second, to address what the scientists perceived as a lack of scientific literacy among the socio-political stakeholders, they advocated for reinforced communication via mechanisms like "shared conferences", "dissemination campaigns" and "school education". Third, the HUMBOLDT scientists recommended the use of a mediator, through scientific journalists for instance, who can act as a translator between the scientific and policy communities: "in our laboratory, we have a person mediating between the scientists and the non-scientific world.

This person actors like a filter that centralises and disseminates information''. These propositions on how science *ought to* be better engaged as the basis for rational decisions, reflects a rather linear and one-directional transfer of knowledge into action, where science remains the legitimate provider of knowledge for fuelling decision-making processes, and where other stakeholders need to be 'educated'.

However, having noted this tendency of HUMBOLDT scientists to depict the science-policy interface in non-social terms, there was also widespread implicit acknowledgement of the social processes operating at the interface. Climate-related science is perceived as permeable to socio-political influences. The scientists discussed their social motivations, i.e., the importance for them of being ''useful'' and creating ''applicable knowledge to support decision-making'', as well as the socio-political pressures bearing on their science: ''decision-makers need scientific data to better govern climatic risks and draw pertinent adaptation policies''. The science-policy interface for climate change is therefore not only perceived as a 'tidy' linear process where science feeds policy, with relationships of influence and power emphasised by the scientists.

That said, the scientists did not appear to be comfortable with the social negotiation of their knowledge. Even if they were ''glad that [their] work is useful'', they emphasised, sometimes in defensive terms, the importance of a demarcation between science and policy in order to maintain the integrity and quality of science: ''We have to separate the scientific questions from the social ones, and remain honest in a context of climate change. But this is not always easy, as insurers or energy companies fund parts of our research''. It is in this ongoing tension between social interests and the independence of science, and between political pressures and integrity of science, that the HUMBOLDT scientists could be found to oscillate. When interactions with the political sphere are too close, it seems that the scientists' frustration is growing: ''What is difficult to explain to governments is that even if [biologists] have applied questions, they need to do more fundamental research''. More particularly, the misunderstanding and at times misuse of uncertainties by socio-political stakeholders is a source of irritation: ''A lot of people are asking us to simplify our message, and try to give black and white answers. So if we start saying that there is uncertainty around this or that aspect of climate change, they will tell us that we don't know anything! But if we don't communicate the uncertainties, then they will blame us for being too catastrophic''.

In conclusion, our scientists recognised that science is a social process, but wanted to 'clean' the messiness of such a process, through demarcation and linear interactions between science and policy, via models, education and mediators.

3.2. The science-policy interface in terms of a 'public deficit model' or as 'dialogue'?

Adopting a different point of view on the STS literature yields a broad distinction on how knowledge is communicated across the science-policy interface for climate change; ranging from those authors who judge the interface in terms of the efficiency and effectiveness of science informing and educating society and policy-makers in a unidirectional way, to authors advocating norms of reciprocal and authentic dialogue. For many authors, the science-policy interface remains an institution for the linear dissemination of information from specialised experts to decision-makers and society, according to what has been labelled a 'deficit model' (Bodmer, 1985; Durant, Thomas, & Evans, 1989; Thomas & Durant, 1987). This model appears to remain widespread even while repeatedly criticised. For instance, Oreskes (2004) highlights ''the benefits that scientists, science, and technology have brought to society throughout history'', while Corner and Randall (2011) discuss how social marketing can be used to inform society of climate change, with a view to changing decisions and actions; appealing to value-based campaigns, targeting social networks and environmental education.

Contrary to the deficit model are those authors promoting dialogue and interaction at the interface; both for constructing knowledge and mobilising it for decision-making. For these authors (e.g., Collier et al. (2011) and Sonnenfeld (2008)), interaction is essential for releasing the knowledge and potential within actors, and constructing a common understanding that is more then the sum of its individual perspectives. For many, this dialogue begins within the different 'communities' themselves; expressed in terms of interdisciplinary science (Jollivet & Legay, 2005) or environmental policy integration (Ishii & Langhelle, 2011). Dialogue is also encouraged across the boundary between scientific, policy, and civil society communities; with this collaboration seem to improve the relevance, compatibility, and accessibility of climate science, while increasing the users' receptiveness (Romsdahl, 2011). Cohen (1999) for example writes about how civil society and scientific communities have grown apart, and are increasingly uncomfortable with each other; such that climate science faces a crisis of trust. The most common form of dialogue analysed at the science-policy interface is between policy-makers and scientists, with policy-makers defining scientific questions and reacting to the findings. Taken to an extreme, this collaboration can be expressed as the co-construction of knowledge (see Section 3.3). Indeed, through dialogue many authors like Collier et al. (2011) and Markusson, Ishii and Stephens (2011) describe the 'social learning' that occurs across all actors engaged at the interface; widely discussed as learning around (i) the issue, (ii) the perspectives of other actors and communities, and (iii) the process of learning itself.

The HUMBOLDT scientists' propositions for linking science and action (as presented above), in particular that of educating socio-political actors, were consistent with the public deficit model.

Non-scientific stakeholders were ‘recognised as parts of the problem of achieving sustainability’, but not included in the creation of solutions (as for instance argued by Rommetveit, Funtowicz, & Strand, 2010). Socio-political stakeholders are not identified as legitimate actors for the knowledge construction process, with their perceived lack of scientific literacy constituting a barrier and a ‘‘source of gradual frustration for scientists, to not be able to say: ‘we know what the problem is, do something about it!’. You have to realise that it is a really long-term process, which can take many years, if not decades, to get the message across’’. This idea of general ignorance as a barrier to effective actions is especially expressed through the scientists’ expectation of valorisation: they appeared not to perceive or recognise that they gain something by interacting with non-scientific stakeholders, as they requested compensation for doing so. Education is thus advocated to increase the general level of knowledge of social and political stakeholders.

Along the same lines, the HUMBOLDT scientists’ plan of using models and indicators in order to support decision-making follows a deficit model as well. Indeed, the interaction proposed by the HUMBOLDT Project does not go beyond a ‘framing model’ (Funtowicz & Strand, 2007) of the issue by relevant socio-political actors, for scientific exploration. Even if it ‘‘increases [the] potential [for scientific tools] to be relevant’’, it remains a ‘forcing’ of non-scientific knowledge into scientific frameworks; considered by the scientists as being the most adequate and legitimate support for action.

Finally, some of the HUMBOLDT scientists’ idea to link science and decision-making through a ‘mediator’ is characteristic of the deficit model. Indeed, ‘interacting’ with non-scientific actors does not involve reciprocal debates and discussions, but boils down to a ‘one-way’ communication, where the greatest challenge for scientists is the simplification of their messages to make them understandable: ‘‘It is very hard for us to know how we can dumb down our message without it losing its meaning and clarity’’.

In conclusion, while the HUMBOLDT project did enable some degree of interaction at the science-policy interface, it retained an overwhelming emphasis on a uni-directional flow of information. HUMBOLDT scientists did allow non-scientific actors into the framing process of their indicators to render them ‘‘local, synthetic, and relevant’’, however they affirmed the importance of ‘pure’ science, and reiterated its legitimacy. As such, it was key for them to reinforce the ‘‘trust’’ in science, as the most legitimate provider of knowledge at the science-policy interface: ‘‘In many countries, the level of distrust of science is high. Unfortunately, the United States recently went through a period of obscurantism where science was not very highly valued’’.

3.3. The science-policy interface as ‘normal science’ or as ‘co-construction’?

A third perspective on the literature illuminates a debate on how non-scientific knowledge is valued and used in support of decision-making. On one hand, we have authors who question the credibility and legitimacy of non-scientific knowledge to steer society’s response to such a complex, uncertain and contentious issue as climate change. For these authors, science is valued as the most powerful means at society’s disposal to support well-founded decisions, with other knowledge, cultures, and mental models undervalued, or indeed seen as barriers (see, e.g., Chen (2011), Lata and Nunn (2011) and Sterman (2008)). There is an understanding that actors outside the scientific community have neither the ability or drive, with Whitmarsh, Seyfang and O’Neill (2011) for instance describing how many in civil society see climate change as a ‘‘spatially and temporally remote risk, affecting future generations and other countries’’. Non-scientific knowledge is rather valued for its ability to augment the existing science, fill any ‘gaps’ and validate scientific models. In this way, non-science is reconciled within a scientific framework, and invited to cooperate and contribute to the science on climate change. This can be described in terms of the scientific community 'extending the olive branch' to other knowledge systems, even as they assimilate and 'scientise' them. Non-science loses its autonomy and character insofar as it becomes subservient to the scientific order. Authors therefore encourage science that 'accounts for irrationality' (Raihani & Aitken, 2011). For example, Krishnamurthy, Fisher and Johnson (2011) discuss ways of 'incorporating and communicating' local knowledge within quantifiable scientific GIS models, while Collier et al. (2011) advocate the use of 'scoping models' to incorporate complexity according to a participatory approach.

Counter to the 'top-down' imposition of scientific models is a literature advocating the 'bottom-up' co-construction of knowledge, within an interface inclusive of all knowledge systems (Wagner & Zeckhauser, 2011). As Edelenbos, van Buuren and van Schie (2011) note, the provision of knowledge is no longer the domain of elites, with science losing its 'a priori authority' to a 'knowledge market', with many suppliers competing to prove the significance and authority of their knowledge. Berkhout (2010) notes that this interface has been buoyed by an increasing public scrutiny of science, intensifying climate politics, and the opportunities provided by new media. Within such an interface, authors describe knowledge as socially constructed with legitimacy largely derived from stakeholders' acceptance of the process (Berkhout (2010) and Edelenbos et al. (2011)); ranging form joint fact-finding, to participatory integrated assessment. Key to these processes is the notion of reciprocity; whereby science and non-science alike are allowed to co-exist and at times contradict, rather than being reconciled into one framework. As noted by Hulme (2011), "rather than consensual and global approaches to knowledge-making [...] we perhaps need to consider spectral and cosmopolitan approaches".

Regarding the science-policy interface as plural, some authors have given special attention to those marginalised stakeholders (see, e.g., Leach, Scoones and Stirling (2010) and Salick and Ross (2009)), such as indigenous or traditional peoples, who are rarely included in these discourses despite being greatly impacted by climate change; advocating principles of equity, social justice and diversity. Beyond notions of justice, a number of governance authors encourage the mobilisation of a diversity of knowledge systems, as a necessity of governance for complexity (Duit, et al., 2010; Ostrom, 2010); according to a hypothesis that institutional diversity and 'polycentrism' is the most effective way to cope with complexity.

With regard to this debate on the science-policy interface as 'normal science' or 'co-construction', the HUMBOLDT scientists largely remained within the first tradition, according to which science is the main and most legitimate provider of knowledge, and all non-science must conform within a scientific framework. In face of the ''need for urgent decision-making to preserve biodiversity'', the HUMBOLDT scientists recommend the creation of a 'scientific consensus' on the issue: ''One of the biggest problems [of climate change] is to provide a clear and unified message to decision-makers''. HUMBOLDT scientists did recognise the need for interaction with non-scientists, but emphasised the over-arching scientific framework - ''The problem of science is that it has stayed away too long from the general public. And now we come back with climate change, and uncertainties in our discourses. This is so disturbing for everybody'' - but the 'framing' of the issue that they advocate does not constitute reciprocal dialogue or co-construction of knowledge. It is rather a way of 'forcing' non-scientific perspectives in an already well-established scientific framework or model. Indeed, this 'framing' remains under the control of the HUMBOLDT scientists: it is their initiative, and as they are guided by expectations of efficiency and results, they can, at any moment, decide to continue on their own.

Beginning from the position that only science can deliver adequate answers to climate change, it follows that climate-related scientists prefer to remain within their scientific community, and communicate results from the safety of this community. Interacting with non-scientific spheres is perceived by the HUMBOLDT scientists as "an additional investment in time and energy"; which leads them to claim that "it is much easier to stay in [our] own discipline and do what [we] know". This characterises how climate science works nowadays, with a valorisation through scientific publications rather than action: "[Interactions with non-scientific actors] are not necessarily the kind of thing that brings publications and things you need in order to make your career move forward".

In conclusion, again we observed the tension between wanting to endorse the exclusive role of science as legitimate knowledge producer; and the wish of scientists to contribute to concrete changes in the environment and in society. Even if they recognised the uncertainties around climate change, they did not appear ready to engage in these debates.

4. Invitation to reflexive dialogue in the context of climate change

For us, this paper reflects the need for reflexive dialogue between the actors of the science-policy interface, in particular climate-related scientists who are the focus here, and the authors who describe this interface, i.e., STS theorists. This reflexive dialogue has, according to us, revealed at least two interesting insights.

First, we believe that our material shows how (natural) climate-related scientists and STS scientists may start from very different perspectives on climate change. While the STS literature pictures climate change as complex, uncertain and appealing for plurality, the scientists of our study, because of the very essence of their work, subscribed to a perspective on climate as knowable and controllable, with holes in the knowledge able to be plugged with the constantly growing scientific scholarship. This results in discrepancies in our perspectives on the science-policy interface, as the way we frame climate change conditions our actions and interactions at this interface. This fundamental divergence emphasises the need for reflexive dialogue, such that both STS scholars and climate-related scientists share and discuss their ontological and epistemological perspectives on climate with a focus on collective action.

Secondly, we have situated the expressed beliefs of the scientists of our study with regard to three issues of debate in the STS literature, with points of convergence and divergence indicating a need for reflexive dialogue between climate-related and STS communities. Indeed, the three debates are quite meaningful in the context of the HUMBOLDT project. There appeared to be a strong relationship between the traditions of 'speaking Truth to Power', 'deficit model' and 'normal science' in one 'group', and the traditions of 'boundary work', 'dialogue' and 'co-construction' in another 'group'; such that actors and authors who may be placed in the traditions of 'speaking Truth to Power' at the science-policy interface are likely also to advocate a deficit model and diminish the role of non-science.

The climate-related scientists of our study belonged to the group from which science is the basis for action; however they realised the existence of the other set of more dialogic traditions. As explained above, the professional role of climate scientists (i.e., modelling reality, predicting the future, and reducing uncertainties), as well as the way science as an institution works, according to standards of truth and objectivity, explains why scientists remain in a 'normal science' approach of the science-policy interface, privileging sound scientific knowledge rather than dialogue across other knowledge systems.

The author of this paper, working mainly from an STS-informed perspective on the science-policy interface, cannot deny her proximity to the group promoting dialogue and co-construction. Rommetveit et al. (2010) criticise the mere use of models and indicators to take decisions, as they draw on questionable assumptions about social, human and economic behaviours and trends. They affirm that in order to adopt sustainable policies, scientists and socio-political stakeholders should shift their endeavour from achieving a 'perfect' knowledge about the future, to collectively reflecting on the social model they want for the present: ''attention needs to be shifted from global goals to societally relevant, local and pragmatic countermeasures'' (Krauss, 2010). Funtowicz and Ravetz (1993) for instance present 'post-normal science' as a dialogic alternative to deal with complex issues. In this approach of climate change, the standards of 'truth' are replaced by standards of 'quality': it is less the knowledge itself than the process of producing this knowledge that ensures its quality and relevance.

Faced by these different perspectives on the science-policy interface between climate and STS scientists, reflexive dialogue is justified for two main reasons. The first reason comes from our participatory action research[5]. The reflexive process established with the climate scientists has indeed helped the HUMBOLDT scientists themselves to recognise the character of the debates from the literature, and some aspects of the science-policy interface that they might not have thought about on their own (Blanchard & Vanderlinden, 2011, forthcoming). By situating themselves within the debates, they were encouraged to recognise the other traditions that they did not commit to. It

[5] Participatory action research often begins with a 'bottom-up' approach with theory nurturing practice. In our case, as the climate-related scientists would talk about the science-policy interface, we would show them aspects of theory that fits to their experience. The co-construction of theory came later.

has helped scientists to deal with the conflict between, on one side, the recognition of the contributions of integrated, participatory, adaptive and critical approaches to complex problems, and on the other side, the preservation of the independence and integrity of science. Indeed, this conflict has led to defensive attitudes from the scientists who felt, understandably, threatened by the prospect of 'post-normality' that would entirely reinterpret their practices and quality standards.

The second reason why we think that reflexive dialogue is important, is the risk of STS and social science becoming arrogant in our attempts at describing and prescribing the shape of the science-policy interface. Indeed, one could argue that those scholarly traditions that effectively refuted the deficit model with respect to public ignorance of natural phenomena, may appear to implicitly hold a deficit model themselves (ourselves) with respect to natural scientists', politicians' and perhaps even the general public's ignorance of social phenomena such as a science-policy interface: 'They do not understand and we need to educate them'. In that case, we might seem to contradict our own ideals of reflexivity and co-construction, dialogue and participation; seeing all attempts to make sense of the world as ''fallible, incomplete, imperfect and risky'' (Strand & Cañellas-Boltà, 2006). Hence, reflexive dialogue is important, not as an imposed tool by STS scholars, but rather to foster discussion and reflection on our own practices, and co-construct theory together with climate scientists. The questions then become: what can we learn from climate scientists? What is practical and pragmatic? There is a need for social scientists to learn about the reality of climate scientists, to understand why, for instance, numerous actors at the interface do not talk about climate change in terms of complexity, uncertainty and plurality, and prefer linear, unidirectional means of action and interaction.

Therefore, in this context, we claim that reflexive dialogue between climate and STS scientists could help us collaboratively to reflect on our future: by fostering reflexivity, reciprocity, openness, respect and authenticity, dialogue between our two communities can engage society as a whole (scientists together with decision-makers and civil society's stakeholders) to collectively formalise common values, priorities and practices along which to apprehend climate change and its various impacts; and hence to reflect upon the model of science and policy they aspire.

Conclusion

This paper has sought to bridge the perspectives offered by the STS literature on the science-policy interface for climate change, and by climate-related scientists active in practice at this interface. By instigating reflexive dialogue between scientists and STS scholars within a participatory action research process, we simultaneously interrogated practice according to theory, and theory according to practice. We identified some important convergences and divergences between what is written on the interface and how this particular group of scientific actors experience it. Perhaps most notably, the two communities were seen to take very different ontological and epistemological representations of climate change, leading to divergent discussions of the interactions and actions at the interface. This paper thus constitutes an invitation to dialogue; an invitation to reflect on the science-policy interface, in the interests of theory that is better grounded in experiences, and actions that are made within a wider acknowledgement of the plural framings of this interface.

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