Governance of learning processes in transdisciplinary research teams

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Abstract

Dealing with grand societal challenges, such as climate change, calls for knowledge production that involves a wide range of knowledge producers and users. Users and producers can engage in knowledge production by participating in 'science teams' that are characterised as 1) involving a large array of scientific disciplines and societal actors; and 2) taking place in a context-specific setting. Much is known about user-producer interactions in the context of technological development. However, the way in which collaborative knowledge production is embedded in the individual, organisational and institutional backgrounds of actors involved is not well understood. This boils down to the following central research question: to what extent do individual, organisational and institutional factors influence the effectiveness of teams consisting of a large range of scientists, users and practitioners, disciplines and locations? We study the characteristics of actors involved in these teams in the context of climate adaptation projects. Event history analysis based on document research and in-depth interviews are used to capture the individual, organisational and institutional factors, and learning processes. The individual, interactional and institutional factors partly explained the level of learning in the urban heat and flood risk teams. The analyses contribute to formulating recommendations on the governance of user-producer knowledge production.

1. Introduction

According to various studies the scientific enterprise has increasingly been subject to calls for societal relevant research. Most prominently, Gibbons et al (1994) and Nowotny et al (2001) view this development as a shift away from science being located in academia and structured by scientific disciplines. They perceive the rise of a new mode of knowledge production, which they call 'Mode 2' knowledge production. In this mode, research is conducted at several sites, not in the least also in the context of application itself. Moreover, disciplinary boundaries are becoming blurred, which leads to integration of research methodologies and conceptualisations. Also on an organisational level, knowledge production becomes more heterogeneous, i.e. during knowledge production several different actors become involved. These actors do not only include academic scientists but also researchers coming from other knowledge institutes, consultants, societal stakeholders, etc. Furthermore, researchers become more reflexive about their role in society. Lastly, the quality control of science turns out to be broader than the traditional peer review system. While the production of knowledge becomes more socially distributed, also the way the knowledge that is produced should be evaluated also becomes broader.

The notion of 'Mode 2' science has been criticised as well (Hessels and Van Lente, 2008). One of the main objections of the concept was the fact that the new way of knowledge production is not as prevalent as was proposed; the new notion was only applicable to a small portion of science. We do not want to redress this discussion here, but it is claimed that some fields are more susceptible to 'Mode 2'. This applies especially to those fields that deal with high levels of uncertainty and complexity of the research subject, concern a variety of normative perspectives and are close to policy-making (Weingart, 1997). In these fields problems often involve high degrees of uncertainties as well as high stakes for stakeholders. These problems are called 'wicked', complex or unstructured (Rittel and Webber, 1973).

One characteristic of wicked problems is that the definition of the problem is subject of contestation as well. If knowledge wants to contribute to shedding light on these problems, Mode 2 science calls for including a wide range of actors in the research process itself. The involvement of a heterogeneous set of societal actors partly legitimises science. Apart from that, they could also be instrumental in the research process and even contribute with their experiential knowledge and creative potential (Boon et al., 2011).

Much is known about the input and output of interactions between knowledge producers and knowledge users. Von Hippel (1978; 2005) showed that user initiatives can form an input to innovation processes, whereas Lundvall and others (1992) emphasised the importance of user-producer interactions in innovation systems. However, hardly any research has been done into the governance of these interactions (Autio, 2004). This paper focuses on the governance of interactions between knowledge users and producers, and how these interactions fit in the prevailing science system.

The broadening of the scientific enterprise has been studied in the context of science and technology studies under terms like user-producer interactions, transdisciplinary research, and knowledge co-production. When focussing on research projects that deal with large, complex problems, the research project team should involve actors coming from different disciplines and backgrounds (science, businesses, government, societal organisations, etc.). These teams form the focal point of science of team science. Team science is defined as scientific endeavours aiming at working on complex problems that call for a cross- and transdisciplinary approach. The science of team science often focuses on those initiatives that encompass a large range of scientists, disciplines and locations (Stokols et al., 2008). Part of these initiatives are organised in the form of large-scale multi-actor multi-level research programmes. Team science teams are hypothesised to be sensitive to peers from science as well as from society. They allow for this because they are either intrinsically motivated or they apply to incentives provided by the science system or society. When studying these teams it is therefore important to take into account the individual characteristics, such as motivations and values, as well as interactional characteristics, such as interaction patterns previous to and during the project, and organisational and institutional factors, e.g. including the prevailing incentive systems. This boils down to the following central research question: to what extent do individual, interactional and institutional factors influence the effectiveness of teams consisting of a large range of knowledge producers and users, disciplines and locations that aim to contribute to ‘wicked problems’?

This paper aims to contribute to the understanding of the individual, interactional and institutional factors and their contribution to team effectiveness, thus adding to the literature on team science, transdisciplinarity and user involvement in science. From a societal point of view, increased understanding of team science might contribute to a science system in which there is more room for integrating disciplines and stakeholder interests, which might lead to integrated solutions for ‘wicked problems’ and the grand challenges that society is facing.

We study this research question in the context of climate adaptation research projects. In the Netherlands, research activities on climate adaptation are organised in two large programmes: Climate Changes Spatial Planning (2004-2011) and Knowledge for Climate (2008-2014). These programmes involve multiple stakeholders acting at different levels. The Knowledge for Climate programme has introduced a novel organisational form. At a regional level policymakers, politicians, scientists, companies and NGOs form ‘hotspots’ in which they co-create research agendas, perform research, and work at translating and implementing research results. These hotspots can be considered interactive learning environments. To explore the factors that influence learning in teams we selected two hotspots in the Knowledge for Climate programme.

The next section delves deeper into theory on knowledge co-production, team science and learning. Section 3 describes the methodology used in this paper. Section 4 presents the results of studying two teams that co-produce knowledge in the hotspots. The final section discusses these results.

2. Theoretical model

2.1 Knowledge co-production

The original idea of the scientific enterprise is that the supply of knowledge is optimised as long as scientists can pursue their interests (Polanyi, 1962). Although this picture still holds some prominence, it should be regarded as one pole of a spectrum of science push and demand pull. Literature on the role of users in innovation processes (Von Hippel, 2005) and the work on analysing the impact of technology on society in the form of technology assessment, at least shows the other half of the spectrum.

This linear view of science production is also visible when analysing the influence of science on policymaking. This is especially prominent in the perspective of scientists speaking truth to power: scientific findings and arguments have a special and often decisive impact on decision making (Lasswell, 1971). However, also in this case there are at least two other perspectives on this science-policy nexus: 'politics on top and science on tap', meaning that policymakers only use science when appropriate; 2) scientists follow their own interests and politicians only legitimise their pre-defined decisions (Hoppe 2005). The two worlds of science and policymaking differ on cultural/empirical and functional/normative characteristics. Although the last perspective suggests that scientists and policymakers live alongside without being interested in each other, these two worlds increasingly interact, and in some cases integrate or even form hybrid agents (Hunt and Shackley, 1999).

This increased attention for the interactions between science, policymaking, but also other stakeholders, such as businesses and societal organisations, might be especially applicable in the context of wicked problems. One of the main characteristics of wicked problems is that the demarcation and definition of the problem is a main part of the research project. In most cases these problems are playing at a larger scale, meaning that the problem definition affects a large array of actors, not merely limited to scientific ones. These scientific projects should therefore be subject to an so-called "extended peer community" (Funtowicz and Ravetz, 1992) involving scientists coming from different disciplines and all kinds of societal actors.

Three bodies of literature discuss the tentative governance of interactions between different stakeholders in the context of wicked problems. First, there is ample literature on the way in which scientists and non-scientists co-operate by guarding the boundary between the two worlds, by this demarcating the tasks of scientist and non-scientists. Taking an active and strategic approach to this demarcation and guarding is defined as 'boundary work' (Gieryn, 1995). Actors who perform this boundary work and who do not belong to either the science or non-science sphere, are called boundary organisations (Guston, 1999). Second, literature on mode 2 knowledge production as introduced in the previous section, focusses on five main attributes: 1) knowledge is developed within the context of application; 2) knowledge transcends existing disciplines; 3) knowledge is produced in a variety of locations, both within and outside academia; 4) knowledge production becomes more reflexive, researchers become aware of the societal consequences of their work; and 5) traditional peer-review is supplemented by new forms of quality control which take economic, political, social or cultural values into account (Hessels & van Lente, 2008). Third, under the label of transdisciplinary research there is an extensive body of literature and research that aims at developing and evaluating new type of research practices particularly suited to address such complex (or 'wicked') 'life-world' (or everyday-life) problems (Bergmann et al., 2005; Hirsch Hadorn et al., 2008; Klein et al., 2001). Transdisciplinary research copes with these "problem fields in a process that integrates a variety of disciplines and actors from public agencies, civil society and the private sector, in order to identify and analyse problems with the aim of developing knowledge and practices that promote what is perceived to be the common good" (Pohl & Hirsch Hadorn, 2007, p.16).

Pohl & Hirsch Hadorn (2007) identified four overarching principles that need to be taken into account when shaping the transdisciplinary research process. Three of these principles relate to the challenges addressed above: they argue that complexity should be reduced "by specifying the need for knowledge and identifying those involved", integration between different types of knowledge should be achieved "through open encounters" and reflexivity should be developed through recursiveness.

1. To achieve effectiveness of research, contextualization is proposed as a fourth principle for the design of transdisciplinary research (Pohl & Hirsch Hadorn, 2007). This entails a second (the first being the dilemma between objectivity and the normative/political aspect of research) main challenge for transdisciplinary knowledge production: how to reconcile two – potentially conflicting - types of knowledge demands. First, a demand for contextualized and action-oriented knowledge coming from practical problems, second a demand for generic and de-contextualized knowledge coming from the academic context.
2. Part of these 'wicked problems' also play on a local or context-specific level. For example, producing knowledge to help create proactive measures to engage with climate change for a large part depends on the characteristics of the location under study.

3. This leads to studies with very specific knowledge that is not easily published in high-impact scientific journals. This is because 1) user- and context-specific questions form the basis of the research objectives, which might not align well with the main cutting-edge scientific questions; and 2) the specific aspects make generalizability harder and make the results and conclusions less appealing to top-tier journals. The incongruence between context-heavy results and cutting-edge issues in high-impact journals is problematic because academic groups are increasingly evaluated using publications in these journals. This development goes on across all disciplines and also applies to disciplines with low levels of reputational competition. The level of reputational competition means “the extent to which researchers seek recognition from their intellectual peers for the significance of their results in solving intellectual problems” (Whitley, 2003). With low levels of reputational competition, other audiences than the ‘international invisible college’ of scientific peers are regarded as more important, also because “goals and reputations are more local than national or international” (Whitley, 2003). At the same time, there is an increasing pressure on academic groups to include societal relevant research in their research project portfolio, and societal relevant research project account for – sometimes substantial – earnings. All in all, research groups increasingly need to combine and align scientific and societal relevant studies. The question is how this can be managed?

All in all, a ‘Mode 2’ approach suits knowledge co-production in the context of wicked problems. These knowledge co-production projects should then take into account the following issues: 1) integration of methods and theoretical perspectives coming from different disciplines; 2) integration of several actor categories, not merely restricting the project to scientists; 3) the development of knowledge production in or close to the context of application. Attention has been paid to the issue of how individual scientists (Pohl et al., 2010) and organisations (Guston, 1999) should act in this hybrid role as boundary agents. Nevertheless, in some cases this boundary work is done in the context of a research team in which knowledge producers and knowledge users participate.

2.2 Team science

The notion of ‘team science’ is borrowed from studies on healthcare research communities. Team science is defined as scientific endeavours aiming at working on complex problems that call for a cross- and transdisciplinary approach. The science of team science often focuses on those initiatives that encompass a large range of scientists, disciplines and locations (Stokols et al., 2008). Exactly the breadth of actors, disciplines and locations involved sets these teams apart from, say, project teams consisting of scientists coming from the same discipline or project teams in companies in which departments, such as marketing, sales, production and R&D, are represented. Research has been done on collaborations in science (cf. Parker et al, 2010) and in the context of projects inside organisations (Hobday, 2000) but most of these studies do not canvas the diverse range of actors, disciplines and locations. For example, in studies on networks more attention has been paid to intraorganisational networks than on networks between organisations (Ibert, 2004; Provan et al, 2007).

The team science teams that we focus here on have the following characteristics:

1. They consist of knowledge users and producers coming from different organisations, disciplines and normative backgrounds.
2. The teams are positioned outside existing organisations. From innovation management we know that organizations facing uncertainties regarding their novel products and services need decoupling (Aldrich, 1979), i.e. set-up innovation projects separate from the business-as-usual operations. This enhances flexibility and might create a nursery that is not (yet) subject to the hard performance criteria. One way of creating such decoupled unit is by founding inter-organisational projects instead of in-house projects (Jones et al., 1997).
3. Interactions need to be deliberately organised and because these teams mostly do not have pre-existing ways of doing, they need to organise the interactions from scratch.
4. The teams might have a single principal but the team members do experience the pressure of at least one other principal, e.g. the prevailing norms in their home organisation.
5. There is a rather definitive research objective that serves as a starting point. At the same time, problem definition and methodology is still inconclusive and open for discussion.

Following these characteristics, these teams should in one way or another deal with the heterogeneity of actors, practices, locations, etc. involved in order to be effective. Three important factors that are particularly important in the context of team science, and which recur in team science literature

(Stokols et al., 2008) as well as management literature on teams in general (Anderson et al, 2004; 2008), are: 1) individual factors, 2) interactional and 3) institutional factors. These factors influence the performance of teams in terms of learning. Figure 1 shows a conceptualisation after which the theory behind the different variables is explored.

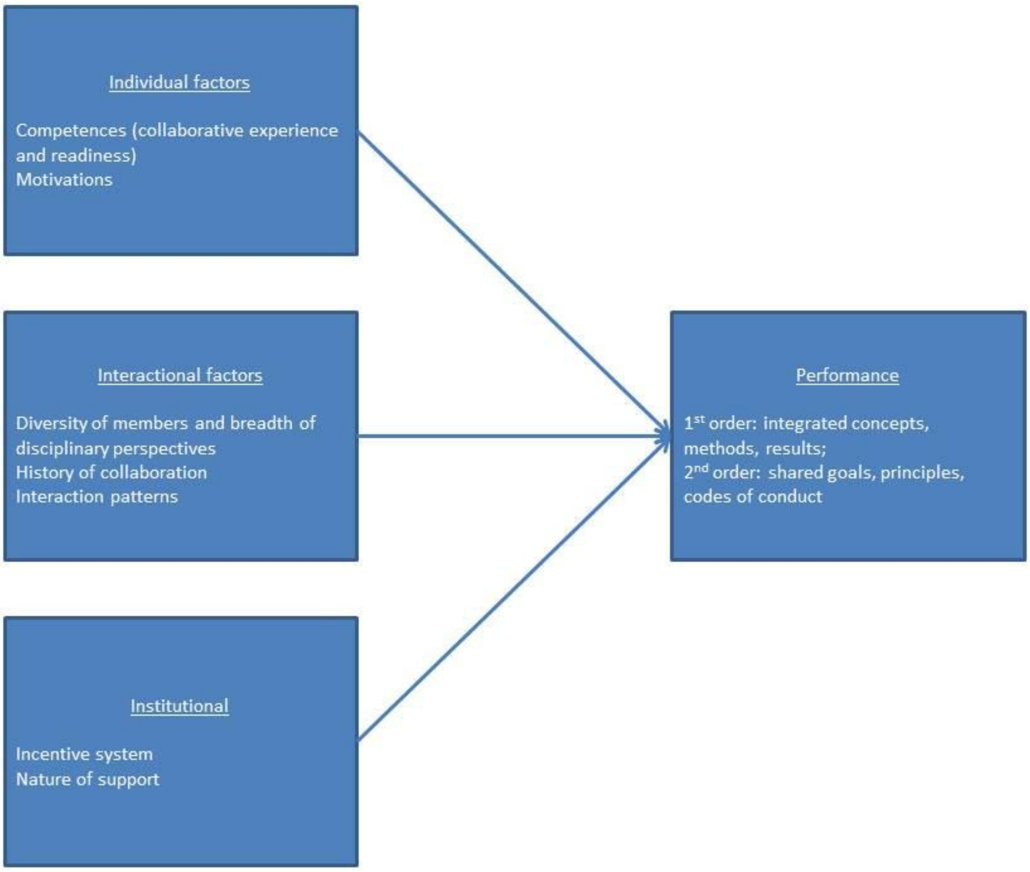

Figure 1: conceptual model of factors influencing the learning performance of team science teams.

The *individual factors* focus two aspects that are relevant for collaboration in heterogeneous and transdisciplinary teams. First, the extent to which the participating actors have sufficient competences to collaborate with such a variety of actors (Hall et al., 2008). Aspects that are important in this context are: the person's experience with transdisciplinary research (and even collaboration with the same partners), and the collaborative readiness. Collaborative readiness is refined as: the theoretical and methodological flexibility to cross disciplinary boundaries and make necessary connections and integrations (Israel et al, 2007); understanding of other actor's values and norms and the willingness to take these into account; and the instrumental contribution to these collaborations in terms of financial and time resources appropriated to the project (Bozeman & Corley, 2004). Second, the extent to which the participants are motivated to collaborate in heterogeneous teams. There are several typologies to characterise a scientist's motivation for collaboration with non-scientists. Lam (2011) differentiates between being not motivated at all (amotivation) and being intrinsically motivated in solving scientific puzzles. In between these two poles there is the extrinsic motivation which could be supported by reputational or financial incentives. Motivation should be included in our analysis because the traditional 'Mertonian' view on science proclaims disinterested research that lacks any motivation to collaborate. Team science provides an alternative to this view by stressing interactions with other (non-scientific) actors, to which different motivations apply. These types of motivations are geared towards scientists. Autio (1996) distinguishes broader categories, viz. educational, political/strategic, financial and epistemic reasons to co-operate. We combine the two typologies in our model.

The *interactional factors* play a role because the team contains a wide diversity of actors, backgrounds, disciplines and locations. In order to collaborate effectively and turn the team's heterogeneity into a positive advancement, communications between team members should be coordinated and stimulated. Frequent interactions lead to learning on the content of the project but also adds to the mutual understanding of values and operations. In this category of interactional factors we first uncover the level of diversity of members and disciplines involved in the team. Moreover, we discern the diversity in organisational practices and routines (Ibert, 2004, p.1533). Second, the starting point of the project should be marked in the sense that historical collaborations with the project members or heterogeneous partners in general (Stokols, et al 2005) should be noted. Subsequently, the interaction patterns during the run of the project should be recorded. These patterns are clarified by taking into account the frequency of interactions and the nature of interactions (cooperative, competitive, regulating, conflicting; Van de Ven et al, 1999). Exchanges take place one-on-one but often also transcend the dyadic relations so also the governance of interactions at team level should be included, e.g. whether there were regular team meetings.

Concerning the *institutional* factors, team science teams are hypothesised to be sensitive to peers from science as well as from society (cf. the extended peer community). In this way, these teams resemble boundary organisations in the sense that they adhere to at least two principals and perform this adherence in different ways (Guston, 1999). The institutional aspect that we consider here is thus the divergence in incentive systems that govern the various project partners. The first step is to what extent project members are directly rewarded by the work they do in the project. The next step would be to uncover the extent to which the work the project participants is taken into account when they are assessed in the context of their own organisation, and whether there are any tensions and pressures between the project work and the work they need for their home organisation (Ibert, 2004). Related to the incentive system is the way in which rewards are handed out in teams. Research in teams working in a company reveals that teams function best when the performance is measured either purely on group output or purely on individual output. So-called ‘hybrid teams’ do not function well (Wageman, 1995). A second dimension of institutional factors is formed by the nature of support provided to team. Team science involves a high variety of actors, mechanisms, etc. which requires higher levels of organised interactions. These organised interactions may take the form of team meetings and brainstorm sessions, which call for time investments additional to the regular research process (Stokols, et al., 2008). The same line of reasoning applies to the administrative aspect of knowledge co-production work. The wide range of actors involved means aligning financial and legal requirements.

Table 1 shows an overview of the three categories (individual, interactional and institutional factors) and the way they are operationalised.

2.3 Learning in teams

Learning in projects and teams can be regarded as rather singular and different from learning in organisations. This follows a set of characteristics of learning in teams (Ibert, 2004; Grabher, 2004): 1) projects often concern research on a contextualised problem field which is in some cases even directly linked to action; 2) projects are often created because of a need for temporal collaboration between actors with heterogeneous backgrounds (March, 1991); 3) projects are also created because of a need for flexible and innovative solutions that are hard to think of by ‘business-as-usual’ business units; 4) project work is done decoupled from organisational routines and norms; 5) and there is a certain amount of definition and commitment to common goals. At the same time, learning is impeded because of the temporal setting and consequential lack of long-term commitment, trust and organisational memory (March, 1991; DeFillippi & Arthur, 1998). Besides that, inside project teams the results might be absorbed but the singular organisational setting and the highly-contextualised nature of the knowledge that is produced makes transferability of the knowledge more complex (Ibert, 2004).

The performance of transdisciplinary teams is conceptualised here as the degree of mutual or social learning. Although social learning originally concerned the way in which actors learn about their environment, later authors like Wenger (1991), conceived learning on the level of social entities such as organisations, projects, and communities. The focus of this conceptualisation was to analyse the creation of shared values, meanings and knowledge. The learning concepts proposed by Argyris and Schön (1978) also went through the same development: at first these concepts were meant to describe a practitioner’s ability and need to continuously reflect on its actions. Later, this reflexive learning was extended to the organisational level as well.

Argyris and Schön (1978; later followed by other authors such as Boon et al. (2011)) conceptualised learning on two levels. On first-order level, transdisciplinary teams need to combine and integrate (theoretical) concepts and methodologies. The development of cross-disciplinary integrations over time is important here, by this emphasising the learning and process aspect of this dimension. Furthermore, the results should appeal to different stakeholders and in such a way are also multi-headed. On the second-order level, teams strive after shared research goals, research principles and codes of conduct. When positively perceived, this learning might lead to continued collaboration, and possibly to better scientific reputation.

Table 1: operationalization of individual, interactional and organisational/institutional factors and team learning.

Category	Independent variable (factors)	Dimension	Indicator	Source
Individual factors	Competences	Individual's experiences with collaboration	No. of projects (transdisc. and/or with the same partners)	Interview
			Level of involvement in previous projects	Interview
			Level of collaboration on formulating research questions, set-up and execution	Interview
		Collaborative readiness	Theoretical and methodological flexibility	Interview
			Understanding of other actor's values and norms	Interview
			Openness to other's values and norms	
			Instrumental contribution (financial, time)	Interview
	Motivations	Educational/ personal/ reputational	Learning and energy obtained through working with other disciplines; expected contribution to career advancement	Interview
		Political/strategic	Legitimisation of research (outcomes); increased chance of implementation	Interview
		Financial/ economic	Financial input creating space for other projects	Interview
		Epistemic/ technological/ intrinsic satisfaction	Need for creative/knowledge input and skills; experiential knowledge; interaction between science and non-science	Interview
Interactional factors	Team diversity (of members and of disciplinary perspectives)	Content	Disciplinary backgrounds	Bibliometrics (and validation through interviews) and CV
			Variety of stakeholders	Network analysis
		Culture	Diversity in organisational practices and routines	Interview
	History of collaboration of team		Joint scientific collaboration	Network analysis based on bibliometrics
			Joint non-scientific collaboration	Interviews and CV
	Interaction patterns	Frequency of interactions	No. of interactions	Network map guiding interview

		Nature of interactions	Cooperate/compete /regulate/conflict	Network map guiding interview
			Informal/formal	Network map guiding interview
		Governance of interactions	Existence of (in)formal meetings	Network map guiding interview
			(In)formal alignment of agreements	Network map guiding interview
Institutional factors	Incentive system	Evaluative mechanisms (formal and perceived)	Indicators used while evaluating work in project	Interview
			Indicators used while evaluating work in home organisation	Interview
			Level of task interdependency: group-oriented, individual-oriented or hybrid	Interview
	Nature of support	Support for coordination	Support for group meetings, etc.	Document analysis
			Administrative support	Document analysis
Performance	1^{st} order learning	Research goals and questions	Formation of common research questions over time	Interview, document analysis
		Methodological approach	Formation of integrated methodology	Interview, document analysis
		Results and outcomes	Integrated presentation of results	Interview, document analysis
	2^{nd} order learning	Values	Convergence/ divergence in values	Interview
		Codes of conduct	Convergence/ divergence in codes of conduct	Interview

3. Methodology

3.1 Case selection

As was mentioned in the introductory section, we studied the Knowledge for Climate programme. This is a large-scale programme that concentrates on researching adaptation to climate change, which is a grand societal challenge. The programme involves a wide range of actors on various different levels. Because it was envisaged that reacting on future consequences of climate change means a large amount of adaptation measures on regional and local levels, the major part of the programme is delegated to nine so-called 'hotspots'. Some of these hotspots are indeed locally concentrated, such as the Rotterdam region and its port and airport Schiphol. Other hotspots are more thematically formulated, such as those focusing on 'dry rural areas' and 'shallow waters and peat meadow areas'.

These hotspots are governed by hotspot teams consisting of stakeholders such as municipalities, water boards, regional authorities, and companies. Research is conducted in three so-called tranches which should ultimately form input for drafting a regional adaptation strategy, which is regarded as a main outcome of the hotspot projects. The idea behind the hotspots is that knowledge is developed as part of a co-production process of scientists, other knowledge agents and societal partners. an important result would be that the knowledge that is produced is more readily included in policymaking and implementation. The first tranche consists of projects addressing urgent knowledge questions based on which subsequent, more scientifically-inclined projects (second tranche) and adaptation strategies (third tranche) were devised. We focussed on the first tranche projects because they are nearly all finished at the moment of study, which means that the certain project output is realised or at least is envisaged. We initially[1] selected two first tranche projects in the Rotterdam hotspot. The

[1] For this paper we report our study of two projects within hotspot Rotterdam. Currently we are also investigating projects in other hotspots and also more monodisciplinary projects (see discussion section).

Rotterdam hotspot was chosen because it had the most wide range of projects in the first tranche and provided for a rich case. The two projects out of a total of nine were selected based on the degree of heterogeneity of actors involved: urban heat and flood risks in unembanked areas.

3.2 Methods

This project uses a mixed-method approach, combining qualitative and quantitative methods. Table 1 shows for every indicator which methods are applied. They include in-depth interviews and document analysis. These different methods are described in detail below.

Indicators dealing with behavioural and attitudinal aspects of team science were questioned using in-depth *interviews*. For the selection of interview respondents we could use the database of all participating persons provided by the Knowledge for Climate programme bureau. A selection was made for every project of persons who were involved content-wise, by this excluding financial administrators and legal representatives. The rest of the persons were approached, making sure that at least of every organisation was represented in the sample. Also, we tried to have a proper balance of senior and junior participants, and academic and non-academic researchers. Table 2 provides a characterisation of the resulting sample, showing that we obtained a near-complete coverage of organisations involved in the three projects.

Table 2: number of actors interviewed (/number of organisations involved in the project) per organisation type and project[2].

	Urban heat	Flood risks
Municipality	1/1	1/1
University	1/1	3/2
Research institute (non-profit)	1/1	2/2
Consultancy firm or engineering agency	2/2	0/1
Company	1/1	0/0

The interviews had an average length of 75 minutes. The interview protocol consisted of open questions. The questions aimed at uncovering interaction patterns were guided by the use of a network map of the project. This network map was drawn on the basis of the aforementioned Knowledge for Climate programme database. Interview respondents were invited to indicate interactions between the actors drawn on the network map. For discussing the major events in the project as well as the significant moments on which first-order learning occurred, we used a timeline as a mnemonic device. By letting the respondents drawing in the what they perceived as important events, we also obtained a starting point to ask about the second-order learning by asking 'why'-questions with every event. Furthermore, it should be noted that the interview respondent was questioned on his/her perceptions and opinions (especially regarding the category 'individual factors' in Table 1) as well as an informant of what happened in these teams (category 'interactional factors' in Table 1).

The interviews were audio-taped and transcribed. The transcripts were sent to the interview respondents for verification. We then analysed the interview transcripts using Atlas.ti, an programme aimed at coding qualitative data. The transcripts were coded in Atlas.ti based on the operationalisation of exhibited in Table 1. Coding was done by two independent researchers and subsequently compared. The coded segments were then summarised for every indicator and included in a table (see next section), which makes comparison between projects and indicators more easy.

The second research methods used was *document analysis*. The main purpose of this exercise was to obtain an overview of the context and content of the projects. This approach uncovered the codified knowledge of the project which could be used to map the most significant events and outcomes of the project on a timeline, adding to the timeline that was drafted during the interviews. The documents were obtained from the project website and replenished with documents provided by the Knowledge for Climate programme bureau and the interview respondents. Besides that, the bibliometric analysis (see below) in some cases also uncovered documents relevant for analysis.

[2] It should be noted that preliminary results are presented in this paper. We will conduct and analyse more interviews in the near future.

4. Results

4.1 Project 1: urban heat

The first project that is investigated concerns a definition study about urban heat island, i.e. the phenomenon that city areas are on average warmer than surrounding areas, and the possible repercussions for health and well-being, the so-called heat stress. The large number of deaths as a result of a heat wave in 2003 formed the occasion for the health effects of heat to be put under the microscope.

The project had a clear chain of research questions: is there a heat island effect? Does that lead to heat stress? What are the causes of the heat island effect? And what measures can you take? These research questions are formed during the preparation of the research proposal and in that period most changes occurred. The research questions are not changed during the research project. Also the methodology was largely fixed and it was to a large extent determined by the choice of the participating researchers. The core project participants include the municipality, three university groups, a public-private knowledge institute, a consultancy company, and a water knowledge institute.

In this project the participants learnt in a linear fashion on the first-order level. That is to say, the questions and methods are aligned in the beginning and during the study these were not changed. The answers to the first research questions (can the heat island effect be discerned?) had influence on later questions in the chain. The results showed that the urban heat island exists, but the effects on human health were far from clear. This outcome offered opportunities for further research, which was duly commissioned, but it proved difficult to extract policy implications from the results. Also at the individual level learning occurred in this project. At the beginning, the policymaker involved no knowledge in this area but she quickly caught up. The scientists saw measuring urban heat as a new topic in the Dutch science field; they could link up with foreign research and needed to devise solutions of their own as well. Furthermore, during the project the team members started to use the same terms, concepts and definitions.

On the second-order level learning also took place, especially about the importance of heat as part of the thinking on climate adaptation and the potential opportunities and threats for politics and policymaking, but also for science. At the start, for instance, the municipality involved wanted to know whether the city was hotter than the surrounding areas and whether this had repercussions for the health of city's participants. The urban heat island was observed but the relationship with health was far from convincing. In addition, several political parties that were not particularly "green-minded" denounced and even ridiculed the research project. This made several actors involved rather uncertain about the objectives of the research project. Moreover, the project did not resulted into a shared vision of urban heat and its consequences, which also did not help to promote the issue.

The other indicators are treated in Table 3 below.

4.2 Project 2: flood risks in unembanked areas

The second project aimed to increase the understanding of flood risks of unembanked areas in the Rotterdam area. Little is known about these risks and a policy is lacking. Still, the effects of climate change, e.g. rising sea levels and changes in river discharge, might influence the risks and consequences of flooding.

This project had a clear chain of research questions as well. They started with the characterisation of the flooding, i.e. flood extent, water depths and flow velocities for the area. Based on these data, flood damages were modelled. Lastly, the vulnerability of the port infrastructure was modelled, based on qualitative expert judgement extracted during workshops. The project leaders were the municipality of Rotterdam and the Port of Rotterdam Authority, a company that develops, manages and operates the Rotterdam port and industrial complex and is fully owned by the Rotterdam municipality. The other core project partners were an university group, one water knowledge institute, and two consultancy companies.

The participants all came from the same disciplinary background, perhaps with the exception of the principals. This meant that learning occurred in the context of their existing knowledge repertoires. The research questions, however, are challenging for all concerned and were perceived as being at the forefront of what they know. Little is known about the valuation of damages due to flooding in unembanked areas and even the calculations of water depths and flow rates were not standard. The research objectives were relatively fixed at the start of the project but there was still room for flexible interpretation of the conceptual and methodological scope. All in all, during the project itself the participants learnt on a first-order level.

In terms of the values underlying the project, all parties were aware that there was little knowledge on the topic at hand. So for various reasons, pure scientific but also commercial reasons, it was interesting for them to participate in the project. In addition, they saw that the unembanked area formed a sort of "outlaw" area was in terms of legislation and liability. This meant that the participants knew well that there was a strong need to fill the blank knowledge spots about flood risks and damages.

Also for this project the values of the other indicators are filled out in Table 3.

Table 3: the values for the indicators for the two projects.

Indicator	Project urban heat	Project flood risks in unembanked areas
Individual factors – competences – individual's experiences with collaboration		
No. of projects (transdisc. and/or with the same partners)	There were two preparatory definition studies that led directly to this project. Only the scientists were involved in these studies.	The participating research organisations are the 'usual suspects' of water research. They previously collaborated on projects. The governmental actors were new to the field.
Level of involvement in previous projects	No previous collaborations between team members.	Between researchers on equal level in the research process.
Level of collaboration on formulating research questions, set-up and execution	Academic push and policy pull decided on preliminary interest in heat issue. Later single participants introduced their 'hobby horse' methodologies.	Municipality and Port Authority articulated their research needs and searched for knowledgeable partners in their own network.
Individual factors – competences – collaborative readiness		
Theoretical and methodological flexibility	The 'hobby horse' methodologies makes it difficult to integrate them, although exchange was necessary on results level as some output formed input for others.	The methodology resulted from previous projects and was further developed in this project. Most research partners perceived the succession of projects as an on-going methodology development.
Understanding of other actor's values and norms	The team members understood each other's values…	The team members understood each other's values…
Openness to other's values and norms	…but self-interests impeded strong exchange and interactions.	…and in general the team members acknowledged the others' values en norms.
Instrumental contribution (financial, time)	Knowledge for Climate contributed 50% of the budget. The other half was put in by the municipality and the participants. Some needed to fight hard to ensure their contribution. All actors thus had sufficient time and resources.	Knowledge for Climate contributed 50% of the budget. The other half was put in by the municipality and the participants ('in cash' but mostly 'in kind').
Motivations		
Learning and energy obtained through working with other disciplines; expected contribution to career advancement	Very important: most participants were highly content-driven.	Very important: most participants were highly content-driven.
Legitimisation of research (outcomes); increased chance of implementation	Moderate.	Fairly important.
Financial input creating space for other projects	Did not play a role at all in pure motivation; for some researchers it was a necessary derivate because	Not mentioned, although the novel subject increased chances of the participants to gain 'pole position' in

	the measurement devices were expensive.	generating new projects on the matter.
Need for creative/knowledge input and skills; experiential knowledge	The participants depended on the outcomes of each other in answering their research question; especially the non-academic partners were very interested in the knowledge of the academic groups.	The participants depended on the outcomes of each other in answering their research question.
Interactional factors – team diversity (of members and of disciplinary perspectives)		
Disciplinary backgrounds	Great variety: the majority of the team were meteorologists, but there were also healthcare professionals and construction and water experts	The majority comes from a variety of backgrounds (biology, artificial intelligence, etc.) but has been working in the water sector for a long time. The municipality and Port Authority representatives only
Variety of stakeholders	7 core participants, 1 subcontractor, 4 interested stakeholders; of which: 3 university groups, 3 research institutes, 2 consultancy companies, 2 municipalities and 2 other governmental organisations	6 core participants, 7 interested stakeholders; of which: 3 university groups, 1 research institute, 2 consultancy companies, the Port Authority, 2 municipalities and 4 other governmental organisations
Diversity in organisational practices and routines	The university groups had an academic way of working, which differed from the way research institutes and consultants worked	There is wide variety of practices but the extremes, such as pure academic and pure policy-related, are not represented in this projects.
Interactional factors – history of collaboration of team		
Joint scientific and non-scientific collaboration	There were two definition studies funded by anther climate programme in which the meteorologists and construction expert worked together. The water and health connection was a first. The governmental organisations were also new to the field.	Although the researchers had been colleagues or part of the same projects, there were no joint publications.
Interactional factors – interaction patterns		
No. of interactions	Infrequent	Frequent
Cooperate/compete /regulate/conflict	The distributed financial contributions resulted in collective decision-making. Distributed mode of governance.	Although several parties contributed (in terms of money or manpower), the municipality and Port Authority were regarded as the principals. Lead organisation mode of governance.
Informal/formal	Formal and business-like	Informal (with exceptions)
Existence of (in)formal meetings	There were project meetings every three/four months.	There were project meetings every two/three weeks.
(In)formal alignment of agreements	The academic partner was the central node of the network in terms of knowledge and vision, and the only interactions took place during project meetings. Later, other parties interacted more directly and some even tried to bypass other actors.	Four research partners and the municipality maintained frequent bilateral contact to co-produce or exchange data. The Port Authority and the consultancy firm worked closely together on a subproject.
Institutional factors – incentive system – evaluative mechanisms		
Indicators used while evaluating work in project	Primarily whether the job was done in the time granted, and the quality of the content. During the project participants checked each other's work. At the end there was an external review.	Primarily whether the job was done in the time granted, and the quality of the content. Quality measured by scientific quality and innovativeness.
Indicators used while evaluating work in home organisation	Policymakers at municipality: planning and budget, plus whether the outcome has any political repercussions. Academic researchers: publications and visibility on conferences. Other researchers: planning and	Most partners were evaluated with indicators like producing new knowledge, trying to have an impact and maintaining/setting-up a new network. Publications hardly played a role.

	budget, networking and to lesser extent publications.	
Level of task interdependency: group-oriented, individual-oriented or hybrid	Every participating researcher was responsible for one subproject. They were evaluated for their own contribution. Thus: individual-oriented.	Every participating researcher was responsible for one subproject. They were evaluated for their own contribution. Thus: individual-oriented. The project leader produced a synthesis report.
Institutional factors – nature of support		
Support for group meetings, etc.	Municipality organised the meetings; Knowledge for Climate assisted with the publications and review procedures.	Municipality organised the meetings; Knowledge for Climate assisted with the publications and review procedures.
Administrative support	Was done by the municipality; there was administrative assistance but also requirements by Knowledge for Climate. On the other hand, researchers also felt an administrative burden.	It was felt that Knowledge for Climate needed to invent the administrative requirements 'on the go'. This resulted in frequent interactions between project leader, members and the Knowledge for Climate bureau, characterised by uncertainty, changing requirements and delays.

4.3 Additional observations

The two cases produce a number of additional observations that are relevant to team science:

1. Different actors involved in the teams have different expectations about the project outcomes.
2. There are marked differences in time horizons: scientists allow a decade for a proper functioning scientific department to emerge, whereas companies and politicians have far shorter time horizons.
3. Working in these teams does not necessarily decrease the risk or the fear that ideas will be stolen. Especially in more homogeneous teams there is an undercurrent of competition.

5. Conclusions and discussion

The two cases that were studied in this paper provide us with new insights into the influence of individual, interactional and institutional factors on the effectiveness of teams consisting of a wide variety of scientists, disciplines and locations that aim to contribute to 'wicked problems'.

The urban heat case concerns a scientific topic that had not been studied in the Dutch context. Scientific and policy-related interests reinforced each other and led to the initiation of the project. In this case, there was a great learning potential and when fulfilled participants could create a competitive advantage based on this knowledge. This resulted in participants being careful in sharing and even attempting to hedge their knowledge. Fuelled by competition they fell back on their own knowledge development. In order to make a significant contribution, team members needed to articulate and stress their own methodology and conceptual approach, which made integration more difficult and – from the participants' point of view – less attractive. This fragmentation can be observed in various indicators (Table 3), such as previous collaborative experiences, collaborative readiness and interaction patterns. Therefore, the knowledge production took place in a distributed way. The institutional factors also severely influenced this pattern because for some parties fulfilling the evaluation criteria of the home organisation was more important than those of the project team. The team participants learnt from each other's outcomes but there were no integrative efforts on a conceptual or methodological level (first-order learning). Moreover, the team members acknowledged each other's norms and values, and they were well-aware that urban heat is a problem that should be dealt with (second-order learning). At the same time, during the project no shared vision on urban heat was formed.

The flood risks in unembanked areas project showed a slightly different story. Here, the clear lack of knowledge was identified by the policymakers and the researchers followed their lead. Some of these researchers had already collaborated with each other, and were now added to the team. This meant that interactions were more informal and they maintained – besides the team meetings – frequent bilateral contact to co-produce or exchange data. Moreover, the parties knew each other, knowing quite well the values and norms, basic processes and evaluation criteria used in the home organisations.

Learning on the first-order level in this project can be regarded as part of a continuous learning process in which the same parties are involved in a sequence of projects dealing with new research questions. Therefore, the team is not only crossing organisational but also project boundaries. Integration of methods and data were more common in this case as well.

This research also has some drawbacks, some of which will be ameliorated during the planned expansion of the investigation. First, the selected cases were all examples of projects that intentionally selected a transdisciplinary and team-based set-up. In view of the research question it would be advisable to also include monodisciplinary projects. Moreover, the Rotterdam hotspot is a large, well-organised initiative that is embedded in other (international) networks and sustainability-driven principals, such as municipalities and politicians. Projects in other kinds of hotspot, i.e. those that are smaller or ill-connected to policymaking or politics, should be focussed on as well. We might get a flavour of the importance of the support ('safe harbour') provided by principals, which could include governmental agencies, knowledge institutes and for 50% also the Knowledge for Climate programme. Second, some indicators are better measured by using other methods. For example, and as indicated in Table 2, the history of collaboration can also be captured using bibliometric analyses. In this way we can also reveal the profiles of the respondents. These profiles include their scientific output, obtained through Web of Science; newspaper articles, through LexusNexus (a Dutch newspaper repository); and their CVs. It could interesting to look whether co-authors really belong to the same scientific field and whether these fields are equally present in the reference list. If that is not the case, maybe these authors did not really collaborated but simply exchanged authorships. These two suggestions will be followed during the continuation of this research.

All in all, the individual, interactional and institutional factors (partly) explained the level of learning in the urban heat and flood risk teams. The focus lies on teams in which a variety of actors, disciplines and locations collaborate, because it is claimed that this heterogeneity leads to richer and swifter answers to wicked problems. This heterogeneity should be dealt with, e.g. in terms of integration of methods and theoretical perspectives and the development of knowledge production in or close to the context of application. This study contributed to observing under which circumstances and factors this variety is resulting into effective learning in research teams.

Literature

Aldrich, H.E. (1979) Organizations and environments. Englewood Cliffs, NJ: Prentice Hall.

Anderson, N., C.K.W. de Dreu & B.A. Nijstad (2004) The Routinization of Innovation Research: A Constructively Critical Review of the State-of-the-Science. Journal of Organizational Behavior, 25, 147-173.

Anderson, N.R. & R.M. Gasteiger (2008) Innovation and creativity in organisations: individual and work team research findings and implications for government policy in Micro-foundaations for Innovation Policy. Amsterdam University Press, WRR.

Argyris, C. & D.A. Schön (1978) Organizational Learning: A Theory of Action Perspective. Addison-Wesley Publishing Company, Reading, MA.

Autio, E., A.-P. Hameri & M. Nordberg (1996) A framework of motivations for industry–big-science collaboration: a case study. Journal of Engineering and Technology Management 13 (3–4), 301–314.

Autio, E., A-P. Hameri & O. Vuola (2004) A framework of industrial knowledge spillovers in big-science centers. Research Policy 33, 107-126.

Bergmann, M., B. Brohmann, E. Hoffman, M. Loibl, R. Rehaar, E. Schramm, et al. (2005) Quality Criteria for Transdisciplinary Research. A Guide for the Formative Evaluation of Research Projects. Frankfurt am Main: Institute for Socio-Ecological research (ISOE).

Boon, W.P.C., E.H.M. Moors, S. Kuhlmann & R.E.H.M. Smits (2011) Demand articulation in emerging technologies: intermediary user organisations as co-producers? Research Policy 40, pp 242-252.

Bozeman, B. & E.A. Corley (2004) Scientists' collaboration strategies: implications for scientific and technical human capital. Research Policy, 33, 599–616.

DeFillippi, R.J. & M.B. Arthur (1998) Paradox in project-based enterprise: the case of filmmaking. California Management Review 40(2), 125–138.

Funtowicz, S.O. & J.R. Ravetz (1992) Three types of risk assessment and the emergence of post-normal science. In: S. Krimsky & D. Golding (eds.), Social Theories of Risk (pp. 211-232). Westport: Preager.

Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott & M. Trow (1994) The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies. London/ Thousand Oaks/New Delhi: Sage.

Gieryn, T.F. (1995) Boundaries of science. In Handbook of science and technology studies. S. Jasanoff, G.E. Markle, J.C. Petersen & T. Pinch (eds.), 393-443. Thousand Oaks, CA: Sage.

Grabher, G. (2004) Temporary Architectures of Learning: Knowledge Governance in Project Ecologies. Organization Studies, 25(9): 1491–1514.

Guston, D.H. (1999) Stabilizing the boundary between US politics and science: the rôle of the office of technology transfer as a boundary organization. Social Studies of Science, 29(1), 87–111.

Hall K.L., D. Stokols & R.P. Moser, et al. (2008) The collaboration readiness of transdisciplinary research teams and centers: findings from the National Cancer Institute's TREC year-one evaluation study. Am J Prev Med, 35(2S): S161–S172.

Hessels, L.K., J. Grin & R.E.H.M. Smits (2011) The effects of a changing institutional environment on academic research practices: three cases from agricultural science. Science and Public Policy, 38 (7), 555-568.

Hessels, L.K. & H. van Lente (2008) Re-thinking new knowledge production: a literature review and a research agenda. Research Policy, 37, 740–760.

Hirsch Hadorn, G., H. Hoffman-Riem, H. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl, et al. (eds.) (2008) Handbook of Transdisciplinary Research. Dordrecht: Springer.

Hobday, M. (2000). The project-based organization: an ideal form for managing complex products and systems? Research Policy, 29, pp. 871–893.

Hoppe, R. (2005) Rethinking the science-policy nexus: From knowledge utilization and science technology studies to types of boundary arrangements. Poiesis und Praxis 3(3), 199-215.

Hunt, J. & S. Shackley (1999) Reconceiving science and policy: academic, fiducial and bureaucratic knowledge. Minerva, 37, pp. 141–164.

Ibert, O. (2004) Projects and firms as discordant complements: organisational learning in the Munich software ecology. Research Policy 33, 1529-1546.

Israel, B.A., A.J. Schulz, E.A. Parker, A.B. Becker (1998) Review of community-based research: assessing partnership approaches to improve public health. Annu Rev Public Health, 19, 173–202.

Jones, C., W.S. Hesterly & S.P. Borgatti (1997) A general theory of network governance: Exchange conditions and social mechanisms. The Academy of Management Review 22 (4), 911–945.

Klein, J. T., Grossenbacher-Mansuy, W., Häberli, R., Bill, A., Scholz, R. W., & Welti, M. (Eds.). (2001). Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society. An Effective Way for Managing Complexity. Basel: Birkhäuser Verlag.

Lam, A. (2011) What motivates academic scientists to engage in research commercialization: 'Gold', 'ribbon' or 'puzzle'? Research Policy 40, pp. 1354-1368.

Lasswell, H.D. (1971) A Pre-View of Policy Sciences. Elsevier, New York.

Lave, J. & E. Wenger (1991) Situated learning Legitimate peripheral participation. Cambridge University Press, Cambridge.

Lundvall, B. (1992) User-producer relationships, national systems of innovation and internationalisation. National systems of innovation: towards a theory of innovation and interactive learning. London, Pinter Publishers: 45-67.

March, J.G. (1991) Exploration and exploitation in organizational learning. Organization science, 2(1), 71-87.

Nowotny, H., P. Scott & M. Gibbons (2001) Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Cambridge: Polity Press.

Parker, J.N., N. Vermeulen & B. Penders (eds.) (2010). Collaboration in the New Life Sciences. Aldershot (UK): Ashgate.

Pohl, C. & G. Hirsch Hadorn (2007) Principles for Designing Transdisciplinary Research. Munich: Oekom Verlag.

Pohl, C., S. Rist, A. Zimmermann, P. Fry, G.S. Gurung, F. Schneider, C.I. Speranza, B. Kiteme, S. Boillat, E. Serrano, G. Hirsch Hadorn & U. Wiesmannetal (2010) Researchers' roles in knowledge co-production: experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. Science and Public Policy, 37(4), pp. 267–281.

Polanyi, M. (1962) Personal Knowledge, Chicago: The University of Chicago Press.

Provan, K.G., A. Fish & J. Sydow (2007). Interorganizational networks at the network level: A review of the empirical literature on whole networks. Journal of Management 33 (3): 479–516.

Rittel, H. & M. Webber (1973) Dilemmas in a General Theory of Planning. Policy Sciences, 4, pp 155-169.

Stokols D., R. Harvey, J. Gress, J. Fuqua & K. Phillips (2005) In vivo studies of transdisciplinary scientific collaboration: lessons learned and implications for active living research. Am J Prev Med, 28(2S2), 202–13.

Stokols, D., S. Misra, R.P. Moser, K.L. Hall & B.K. Taylor (2008) The ecology of team science - Understanding contextual influences on transdisciplinary collaboration. American Journal of Preventive Medicine, 35(2), S96-S115.

Van de Ven, A.H., D.E. Polley, et al. (1999) The Innovation Journey. Oxford University Press, Oxford.

Von Hippel, E. (1978) A customer-active paradigm for industrial product idea generation. Research Policy 7: 240-266.

Von Hippel, E. (2005). Democratizing innovation: the evolving phenomenon of user innovation. Advancing knowledge and the knowledge economy, Washington.

Wageman R. Interdependence and group effectiveness. Adm Sci Q 1995;40:145– 80.

Weingart, P. (1997) From “Finalization” to “Mode 2”: Old wine in new bottles? Social Science Information 36 (4), 591–613.

Whitley, R. (2003) Competition and pluralism in the public sciences: the impact of institutional frameworks on the organisation of academic science. Research Policy 32, pp 1015–1029.

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