Neurons in the Network

Learning in Governance Networks in the Context of Environmental Management

Jens Newig[1], Dirk Günther[2], Claudia Pahl-Wostl[3]

2009-07-04

Contribution to special issue, eds. B. Crona / K. Hubacek

Abstract

In the face of apparent failures to govern complex environmental problems by the central state, new modes of governance have been proposed in recent years. Network governance is an emerging concept that has not yet been consolidated. In network governance, processes of (collective) learning become an essential feature. Collective learning refers to cognitive changes in individuals within a network and is moreover understood as a process in which individual changes in cognition lead to modifications in collective institutions. The key issue this paper seeks to approach is the mutual relation between network structures and collective learning with the aim to improve environmental management. As of now, there have been few attempts to apply techniques of Social Network Analysis (SNA) to collective learning and governance issues. Given the ambiguities of the concepts at stake, we begin by explicating our understanding of both networks and collective learning. We consider learning-related functions that networks can perform to different degrees: information transmission, deliberation, and resilience. We address two main research questions: (1) What are the characteristics of networks that foster collective learning in each of the three dimensions? To this end, we consider SNA-based network measures such as network size, density, cohesion, centralisation, or the occurrence of weak vs. strong ties. (2) How does collective learning alter network structures? We conclude by outlining a number of open issues for further research.

Keywords: Social Network Analysis, Network Governance, Effectiveness, Resilience, Deliberation, Information Diffusion.

1 Introduction

In the face of apparent failures to govern complex environmental problems by the central state, top-down policy-making and new modes of governance have been proposed in recent years. *Network governance* is an emerging concept that has not yet been consolidated. With its roots in the economic (Jones et al. 1997) and policy networks literature (Kenis and Schneider 1991; Scharpf 1997;

---

[1] Institute of Environmental and Sustainability Communication, Leuphana University Lüneburg, Germany, e-mail: newig@uni.leuphana.de.

[2] Umweltbundesamt, Dessau, Germany. e-mail: di.guenther@googlemail.com. The opinions expressed in this contribution do not necessarily represent those of the Umweltbundesamt.

[3] Institute of Environmental Systems Research, Osnabrück University, Germany, e-mail: pahl@usf.uni-osnabrueck.de.

O'Toole Jr. et al. 1999; Haas 2004; Torfing 2005), network governance is increasingly being proposed to cope with sustainability problems (Dedeurwaerdere 2007).

Two different lines of reasoning as to why and how this approach helps improve environmental governance can be identified. From an (economic) transaction cost approach, networks are viewed as an intermediate form of governance between hierarchies and markets, allowing actors to react flexibly to complex, uncertain and changing environmental conditions (compared to hierarchies) while being more stable and reliable than pure markets. Second, the creation of networks allows the different sources of knowledge and competences provided by the different actors to be integrated, especially when the network structure fosters efficient information sharing and social learning (Cross et al. 2004).

However, if network governance is considered to do more than merely involve the relevant stakeholders and interest groups in decision-making, then processes of learning both on the individual and on the collective levels become an essential feature (Knoepfel and Kissling-Näf 1998; Siebenhüner and Suplie 2005). Collective learning not only refers to cognitive changes in individuals within a network, serving as a structural framework, but is moreover understood as a process in which individual changes in cognition lead to modifications in collective rules/institutions, either by consensus or by some other mode of aggregation. These may, in turn, feed-back to learning processes on the individual level.

These approaches assume that *whether or not governance is conducted in networks makes a crucial difference* for individual and collective learning and, indirectly, for the 'quality' of governance outcomes. Networks, of course, differ in size, composition, intensity of communication, density and other structural properties. We can therefore generalize the above hypothesis as follows: *The properties of a governance network have an impact on individual and collective learning in the context of environmental management.*

Stunningly, the impact of networks *as a whole* has until now received very little attention in the scholarly literature. This stands in stark contrast to the wealth of publications on the impact of single actors or actor groups *within* networks (Provan and Kenis 2007). Moreover, the effects of network (structure) on governance-related variables such as learning have been under-researched, leaving the question of "do networks matter?" still open (Raab and Kenis 2007). Only very recently, a perspective in which network structure is considered as an independent variable, is emerging (Bodin et al. 2006; Prell et al. 2009).

A rich and most useful toolbox for analysing network structure has been developed in the field of social network analysis (SNA). This provides mathematical measures e.g. of density or centralisation of whole networks. At the same time, a quickly growing body of literature deals with the role of collective learning for environmental management. However, SNA has hardly ever been related to the issue of collective learning and governance issues (Kenis and Raab 2003), whereas the collective (or social) learning literature, while it does acknowledge the role of networks, has hardly made use of SNA.

This paper aims to bridge this gap and make a first attempt towards integrating the (collective) learning and network governance literature with SNA measures. This allows to sharpen the concept of learning in networks by way of employing formal SNA measures and at the same time to formulate hypotheses on the relation of network properties with learning. Given the ambiguities of the concepts at stake, we begin in section 2 by explicating our understanding of governance networks and briefly introduce SNA. In section 3, we define different forms of learning in networks. Subsequently, in sections 4 and 5 we address the two main research questions: What are the characteristics of a network that foster collective learning in the context of environmental management? How does collective learning, in turn, alter network structures? We conclude (section 6) by outlining pathways for further research.

2 Governance Networks and Social Network Analysis

Social networks can be defined as a group of actors connected to each other by interdependent social relations (Schweitzer 1988). Within these groups, mutual formal and/or informal norms and values exceed those necessary for market transaction, but they do not accomplish the hierarchical top-down, command and control structure. Governance networks have been defined by (Torfing 2005, p. 307) as "(1) relatively stable horizontal articulations of interdependent, but operationally autonomous actors who (2) interact with one another through negotiations which (3) take place within a regulative, normative, cognitive and imaginary framework that is (4) self-regulating within limits set by external forces and which (5) contributes to the production of public purpose". From this definition, three aspects are particularly worth noting in the present context: First, the "relative stability" that networks exhibit allows a structural analysis as can be done by SNA methods, which will be discussed below. Networks thus can be described as institutionalised communications. Second, networks have a cognitive dimension that involves information transmission and learning processes. And third, governance networks are related to public purposes, distinguishing them from other kinds of networks. Depending on the specific type, governance networks can be created, encouraged or maintained by a central steering actor (such as the state), which either directly takes part in a network or supervises it from outside (Dedeurwaerdere 2007), but this need not be the case.

Governance networks, as defined above, are a theoretical construct that relates to an empirical phenomenon. The delimitation of networks is not without difficulty. Social networks in general, and governance networks in particular, need not – and seldom have – a well-defined boundary. If for analytical purposes networks are defined according to a limited set of actors, the network boundary is indeed given by definition. This can be the case if organisational membership or geographical location determine who belongs and who does not belong to a network. However, here the network concept may become blurred with the group concept. If, as more commonly the case, networks are defined according to the relations they have, networks may become infinitely large, unless the network relations are defined in a very specific manner. An often-used criterion is the frequency of interaction among network members as opposed to non-members (Wasserman and Faust 1999). Governance networks, in particular, may be defined by those members who commit themselves to the governance task at hand (Knoepfel and Kissling-Näf 1998).

Networks can build up structures of regulatory frameworks and norms for interaction and decision-making processes, which constitute the institutional factors of networks. These structures are not so strong as in organisations and under hierarchy but are tighter than in pure market circumstances. The common focal point is the governance problem and reality perception that forms, for instance, "epistemic communities" (Haas, 1992: 3). Although participation in these epistemic communities requires an interest in the problem at stake, the actors involved do not necessarily share the same interest. In general, their interests are interdependent but can also be different or sometimes contesting, stressing the need for negotiation, consensus-building and the development of cognitive commodities.

This highlights the important role of the quality of the relations in the network to enable it to fulfil its governance functions (see below). Granovetter 1973 distinguishes between strong and weak ties to characterise the intensity and quality of the linkage between actors. Strong ties are characterised by solidarity and trust between two actors. They are the basis of societal influence and social capital in networks. However, an actor's number of strong ties is limited since the implementation and maintenance of this kind of relation is time-consuming and requires a lot of attention. In contrast, weak ties are less redundant and more flexible than strong ties. Hence, they can bridge longer distances within a network, thus providing new information and knowledge for the network. Moreover, weak ties can link the members with other actors of a policy arena outside the boundaries of the network. However, due to the loose but flexible linkage between the actors, weak ties are not suitable for creating trust, shared values and norms.

Insofar as network structures are mainly based on the bilateral trust of actors to respect the mutual normative frameworks, they enable an environment of problem-oriented interaction and decrease the actors' transaction costs. This leads to stable relations, facilitating the development of collective action (Ostrom 1990) routines. On the other hand, the trust between actors also emerges with the danger of a closed common "world view" of the actors. In the long run, therefore, networks tend to stabilise linkages, decision and action routines and attitudes. This endangers two effects. First, the long-term stable relations between actors without "fresh" perspectives from outside can lead to the inflexibility of the network and "cognitive blocking" (Messner 1995), disabling the network to react adaptively and innovatively to new challenges. This leads to an attitude of non-learning. Second, on the basis of their long-term, trustful and stable relations, actors develop the tendency to include social enclosure and path dependencies in their actions. This group thinking (Janis 1982) builds a stable paradigm that only allows incremental changes in values, beliefs and action within the specific framework of reality perception. Paradigm shifts (radical changes) can hardly be implemented in these networks.

The advantages of networks as deliberative structures at the so-called "meso-level" between the market and hierarchy, which incorporates different knowledge sources and competencies, led to an uptake of networks as a governance approach in the late 1990s (for an overview see, for example: Diani and McAdam 2003; Haas 2004; Ostrom 2001; Reinicke and Denkg 2000. By incorporating actors from different sectors, the approach aims to provide an innovative environment of learning, paving the way for adaptive and effective governance (Dedeurwaerdere 2007). Since networks use a "paradigmatic governance" approach (Fürst 2002) based on a shared normative framework of values and rules, they can help institutions to work more smoothly and adaptively in a dynamic environment. The mutual paradigm of the network allows them to act collaboratively without permanent negotiating action rules and norms. However, the danger of the failure of these structures is also incorporated in the network approach itself. According to Messner 1995, network governance approaches will fail under the following conditions:

- The actors do not develop a common problem-solving orientation but only follow their own lobby orientation (Olson phenomena).
- Previous experiences with the mechanism of collective consensus-building and conflict resolution network structures are lacking. This can lead to endless disagreements.
- The development of "generalized trust" between actors as a major precondition for network success fails because of a lack of institutions.

These points underpin yet again the relevance of the properties of the network with regard to the successful appliance of the network approach. Tichy et al. (1979) distinguish between three sets of network properties:

- Transactional content (exchange of effect, influence and power, information, goods and services).
- Nature of the links (intensity, reciprocity, clarity of expectations, multiplexity).

- Structural characteristics.

While the transaction content and nature of links focus on linkages between pairs of actors, the structural characteristics describe the network as the whole. Social science research has developed a wide range of instruments to describe and evaluate network characteristics. To analyse networks in a standardised and formalised manner, the methodology of social network analysis (Everett and Borgatti 2005; Scott 2003; Wasserman and Faust 1999) has meanwhile become rather advanced and elaborate. Social network analysis (SNA) provides numerous definitions and mathematical tools, derived from graph theory, that allow for a stringent description and analysis of network structures. The only information that is considered in SNA is which actors are related to on another and possibly the direction and numerical 'strength' or 'intensity' of these relations. The quality of actors themselves (such as competences), their geographical distance or the qualitative nature of the relations are not considered. Basically, SNA distinguishes between measures related a) to single actors (such as centrality), b) to subsets or 'cliques' within a network and c) to whole networks. The present paper will use measures that characterise the structure of networks as a whole – an aspect that has so far received only little attention in the literature (Provan and Kenis 2007).

Given the wealth of 'network' concepts in the social science literature, it is important to note what we do *not* mean when speaking of networks. Two examples of popular network approaches shall demonstrate this. First, we do not consider the approach of a 'network society' by Castells 1996. In his impressive work, Castells argues that global networks are heavily on the rise and gives numerous examples supporting this idea. However, Castells does not provide mechanisms as to how networks function or what role they play in governance. Second, the 'actor network theory' (ANT) by Latour 1996 has gained popularity especially in sociology. As Latour explicitly incorporates non-human actors (or actants) in his approach, the study of governance networks can hardly profit from these ideas.

3 Individual and collective learning in networks

In the following, we shall first discuss what learning on an individual level means and how this can be fostered in governance networks. We argue that networks need to serve certain functions in order to provide an environment conducive to learning in the context of environmental management. Subsequently, we extend this concept to learning on the level of the network itself, i.e. collective (or social) learning. Both forms of learning can be 'shallow' or more 'deep', applying the concept of single-loop and double-loop learning to learning in networks.

Learning

In a wide definition, learning refers to cognitive changes (Miller 1996). In a stricter definition, learning involves not only cognitive but also behavioural change, i.e. only when cognitive change manifests in changed action, one can speak of learning (Argyris 2003). In this paper, we accept both definitions and acknowledge that learning has already taken place when – on the individual level – people acquire new knowledge or change their perceptions of the environment. While learning can involve all sorts of dimension, we are particularly interested in those that are conducive to network outputs in the context of environmental management.

Learning is a form of information processing. The general hypothesis behind learning in networks is that networks provide an *access to novel information* and *influence the way information is being processed*. Access to novel information is provided by regular communication with other network members. These also exert influence on information processing, e.g. by copying from others (Bandura) or through deliberative processes in which arguments are exchanged and perceptions change through persuasion.

Learning-related network functions

These considerations lead us to distinguish two key functions that networks need in order to foster learning: information transmission and deliberation.

- *Information transmission:* Through the interaction and communication of actors, knowledge and information can be transmitted among the actors (information distribution or diffusion, see e.g. Valente 2005). This is a first prerequisite of the (collective) learning of actor groups. Actors gain access to relevant information and other participates' knowledge with relatively low effort as compared to a non-network situation. Arguably, the potential of a network to allow information transmission depends to a considerable extent on the network structure and the involved actors.
- *Deliberation:* Based on ideas by Habermas (1981), deliberation refers to a genuine exchange of ideas and arguments regardless of societal power asymmetries. Networks are expected to provide opportunities for deliberation, e.g. by way of group interactions. Through intensive group interactions deliberation is expected to produce more creative ("emergent") ideas and solutions as compared to a situation in which actors are reasoning by themselves.

Next to these basic network functions that pertain to learning, we introduce a third network function that forms a fundamental prerequisite for maintaining network functions: network resilience.

- *Resilience:* Network resilience denotes the capacity of a network to remain intact in its basic functions when subject to pressure or sudden change (Berkes and Folke 1998). For instance, if an important actor in a small, non-redundant network structure suddenly disappears (e.g. by leaving the network or by disease or death), the whole network might have severe difficulty in maintaining its function or may even break up. Therefore, a certain redundancy of both competencies and network relations makes networks less vulnerable and therefore potentially more effective with regard to its learning-related functions.

Collective learning: change of neurons in a social network

Learning on an individual level involves changes in cognitive structures of individual brains. Collective learning (or social learning) in its stricter sense pertains to learning on a collective level. Social learning in the sense of Bandura (1977) involves learning of individuals by copying from others (rather than making experiences oneself). For the purposes of this paper, this type of learning would still be considered individual learning since learning takes place by an individual, i.e. *within* a collective but not *by* a collective. In practice, collective learning typically involves individual learning as well. In this sense, collective learning requires the transmission of knowledge among individuals.

Collective learning means that social structures change. Social structures can be institutions in the broadest sense: informal or formal norms (collective decisions, policy outputs) or institutionalised communication structures such as networks. Taking up the analogy of individual learning as change in cognitive structures (linkage of neurons in a brain) then collective learning in a network can be regarded as a change of neurons (linkages) in a social network.

Schusler et al. 2003 define collective (social) learning as "learning that occurs when people engage one another, sharing diverse perspectives and experiences to develop a common framework of understanding and basis for joint action" (p. 31).

In contrast to individual learning, collective learning not only refers to cognitive and behavioural changes in individuals within a network, serving as a structural framework, but is also moreover understood as a process in which individual changes in cognition and action lead to modifications in collective rules/institutions. Collective learning is strongly related to the concept of social learning (Hall 1993), which sees the sources of a decision-making process not only in power and interests, but also in a growing capacity of social entities to perform collectively on common tasks on mutual norms in a context of uncertainty and common puzzling. Social learning implies "learning about the dynamics of change of the human system and the ecosystem, about the mental frames that shape decision making, and the biophysical and social consequences of change" (Pahl-Wostl 2002: 401; see also Tippett et al. 2005). To respond to the expectations and challenges formulated from different perspectives, social learning must be conceived as more than just cognitive learning. "Learning together to manage together" also involves changes in attitudes, beliefs, skills, capacities, and actions in and among the counterparts (Pahl-Wostl et al. 2007).

Collective learning in governance networks bears similarities to policy learning, as conceptualized e.g. by Sabatier 1988. Policy-oriented learning refers to "relatively enduring alterations of thought or behavioural intentions which result from experience and which are concerned with the attainment (or revision) of policy objectives" (Sabatier 1988: 133). It is important to note that learning is not everything, and not everything is learning. Not all policy *change* is due to learning! Regularly, policy change is merely due to (collective) *decisions* that result from applying decision tools or algorithms or from bargaining processes that leave the preferences of actors as well as network structures unchanged.

Single and double loop learning

This transfers the term learning to a more abstract level, which concerns the underlying values, beliefs and attitudes of the actors (group). Hence, it is necessary to disaggregate learning and conceptually distinguish between different forms of learning. Argyris (1982) developed the concept of single loop and double loop learning, which is valuable in this sense. Both forms lead to new or improved knowledge which will lead to changes in the cognitive structures. The concept argues that single loop-learning occurs when an experience has led to the detection of a mismatch, which is corrected without changing the underlying values, but remains within the accepted routines. In double-loop learning, however, the detected mismatch leads to a change of the underlying paradigm (Argyris 1982). The change in the paradigm requires as well new rules of conduct and routines (Argyris 2003).

	Single-loop learning	**Double-loop learning**
Individual learning	Learning of new facts Correction of practices	Change of assumptions and values
Collective learning	Punctual change in network structure Policy output: change of rules of operational choice	Fundamental change of network structure; Building of network resilience Policy output: change of rules of collective-choice

Table 1: Relation of single and double loop learning to individual and collective learning.

This concept can be aggregated to networks and social learning (see table 1). An actor group reflects on the experiences of collective action, transfers information and knowledge individually gained among the actors and adapts the way how to reach a goal (single-loop learning). Double loop learning implies a reflection on the goals themselves and on the interrelations between the network members (Swieringa and Wierdsma 1992; Maurel 2003; Pahl-Wostl in press). Then, learning also affects the common rules and institutions of the network, which represents collective learning.

Depending on the level of learning (single- or double-loop), networks can support or impede learning efforts. In particular, in long-term stable network relations (strong-ties), double-loop learning is difficult to achieve since the effect of social closure and group thinking will hinder actors to reflect about goals, norms and rules. Double-loop learning processes, i.e. shifts in the paradigm, will mainly occur in the (re-)formation phase of a network (Döhler, 1993; Pahl-Wostl in press). Whereas single-loop learning is generally supported by network structures, information flow and the adaptation of the same are supported by mutual trust and the common normative framework. Nonetheless, first- and second-order learning also have the effect of structural change on the network relations over time.

4 Network characteristics fostering learning

Having discussed different kinds of learning in networks, we will now examine the impact of network structure on the potential for learning. What difference does network structure make? We will draw on a number of whole-network measures provided by social network analysis (SNA) methods. This includes quantitative measures as well as qualitative characteristics such as the interaction content and the nature of the network relations. Normally, we assume network relations to be any institutionalised communication, i.e. that actors communicate regularly about issues of environmental management. According to Tichy et al. 1979, relations between actors can be based on the exchange of effects, information, influence and power, or goods and services. In general, all content features can support the single-loop learning of actors, as they all provide experiences that can be reflected, leading to a change in behaviour. However, information and influence relations are more conducive to learning than relations of the exchange of goods and services.

In the following, we will discuss the potential effect of network size, density and multiplexity, cohesion (absence of structural holes), centralisation, homophily and the relation of weak to strong ties. These characteristics can be adverted to the three functions of social networks (information distribution, deliberation, resilience) and to the levels of learning (see table 2 for an overview).

Network size

Network size is defined by the number of actors in a network. In SNA, this presupposes a clear delimitation of the network: actors are either part or are not part of the network. For very small networks, one can assume a positive relationship between network size and various learning effects: The more actors there are, the more there is to learn from them in any respect, and the more resilient the network is. As networks become larger, this relationship is less obvious. Large networks can make it difficult to engage in deliberative exercises. For instance, experiences from case studies demonstrate that an ideal group size for deliberation is about 8-15 actors (Craps 2003). However, deliberation in medium-sized groups may as well occur within a larger network. This requires analysis of cohesive subgroup (Everett and Borgatti 1999). Generally, larger networks are likely to exhibit stronger resilience as, e.g. the exit of actors or the termination of relations can more easily be replaced by others in the network. Information transmission can also be expected to increase with network size, provided that other factors (such as density) remain constant (which, however, is rather unlikely).

Network function / Network characteristic	Information transmission	Deliberation	Resilience	Single-loop learning	Double-loop learning
Network Size	+	+ / - (convex curve)	+	+	+ / - (convex curve)
Homophily (average)	+	+	+	+	○
Multiplexity (average)	+	+	+	+	–
Density	++	+	+	+	–
Cohesion / absence of structural holes	+	++	+	+	–
Relation of weak to strong ties	+	–	○	○	+
Centralisation	+	–	–	+	+

Table 2: Hypothesised influence of network characteristics on the performance of network functions. '+': high (low) values in the independent variable lead to high (low) values in the dependent variable; '–': vice versa; '○': no discernible or unclear influence.

Nature of network relations / homophily, multiplexity

The transactional content features of the linkages between actors can be characterised by the terms intensity (strengths of a relation between individuals, i.e. strong and weak ties), reciprocity (degree to which a relation is perceived and agreed on by both parties of the relation), clarity of expectations (degree to which the pair of individuals has clearly defined expectations about each other) and multiplexity (degree to which pairs of individuals are linked by multiple relation contents). To support learning, relations in a network should be characterised by a high degree of intensity, reciprocity and multiplexity. These three characteristics are the basis of trust among the actors, which is needed to develop a learning-supported environment. However, high values in these characteristics can also indicate a cognitive blocking situation that does not allow double-loop learning and hence radical changes and a paradigm shift.

In contrast, a high degree of interaction frequency is supposed to be beneficial for both single- and double-loop learning. Interaction frequency, however, has to be distinguished from relation intensity (Marsden 1990). The frequency of interaction can support the intensity of the relation. This, however, does not necessarily lead to the better quality of the relation (higher intensity). However, actors with a high frequency of interactions with a greater number of other actors in the network can be valuable for including in information sharing and dissemination (Hubacek et al. 2006) but also for initiating and fostering a shift in institutional settings. This also means an actor's high degree of centrality, i.e. the degree to which how centrally a specific actor is positioned in the network is valuable for collective and collective learning in networks. A central actor can bridge the network across boundaries and distribute the information to a high number of network members. Hence, it is moreover valuable for learning within a network if these central actors are linked to the surrounding policy area via boundary-spanning relations (Liebeskind et al. 1996). The characteristic 'openness', defined as the number of actual external links of a social unit in relation to the number of possible external links (Tichy et al. 1979), illustrates this.

In principle, human communication theory states that the distribution of knowledge and flows of ideas mostly occur between individuals who are similar, or homophilous (Rogers 1995:18). Homophily is the degree to which two actors in a network interacting with each other have certain similar attributes. For information flows leading to single-loop learning, this is an advantage. A network with a high degree of homophily is supposed to distribute information and knowledge more quickly, i.e. the actors have a better source to learn. Again, for a paradigm shift to double-loop learning this is not that clear. Effective information and knowledge distribution is needed here, too. Nevertheless, homophilous actors also tend to close their perceptions to outside information.

Network density and cohesion

Network density is defined as the number of relations in a network divided by the maximum possible number of relations when (actors directly related). The denser a network, i.e. the more relations exist in a given network, the more easily information will be transmitted. In a less dense network, information can become distorted when transmitted via a great number of different actors. This has been shown in different studies (Abrahamson and Rosenkopf 1997; Valente 2005). Deliberation, as well, is more likely to occur in dense networks, because groups in which many actors know each other show more potential for deliberation. Deliberation in particular is supported by a high cohesion, i.e. absence of structural holes in a network (Coleman, Gargiulo and Benassi 2000). Very dense and strongly cohesive networks, on the other hand, tend to be less able to adapt to fundamental change, e.g. by restructuring the network (double loop learning) (Burt 1992; Gargiulo and Benassi 2000) because they tend to be "trapped" in their own groupthink. Strutural holes offer further opportunities for emergent leadership and collaborative innovation. Individuals can exploit structural holes to act as brokers and connect otherwise disconnected groups and promote thus innovation and learning.

Weak and strong ties

The strength of a network relation (tie) has been defined as "a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services that characterize the tie" (Granovetter 1973, p. 1361). Typically, weak ties are less redundant and more flexible than strong ties. Hence, they can bridge longer distances within a network, thus providing new information and knowledge for the network. Moreover, weak ties can link the members with other actors of a policy arena outside the boundaries of the network. On the other hand, deliberative processes with intensive exchange of arguments tend to work better with strong ties. Taking up arguments from complex systems theory (Gibson et al. 2000; Newig and Fritsch 2009), modular networks consisting of several cohesive subgroups with strong ties and several weak tie relations within the broader network can be expected to provide the strongest environment to foster learning.

Network centralisation

Network centralisation is a measure of how 'uneven' centrality is distributed in a network. Centrality is an actor-related measure and can be defined in different ways that all relate to the 'importance' or 'power' of an actor in a network. For instance, degree centrality is the number of directly related actors in a network; closeness centrality is a measure of how easy an actor can reach any other actor in a network. Typically, centralisation is defined as the centrality of the most central actor(s) divided by that of the least central one(s). Regarding consensus on values and goals, more centralised networks combined with a high opinion leadership of the central actor are regarded as more suitable. However, overly centralized networks are also seen as vulnerable because of their strong reliance on a few heavily linked individuals. Experiences from various case studies show that networks and hence learning processes will collapse if an actor with high option leadership leaves the process (Nicolini and Ocenasek 1998).

Information transmission is typically easier in centralised as opposed to decentralised networks (Leavitt 1951; Crona and Bodin 2006). Given a similarly dense network, a more centralised one will allow information to flow quickly from, say, a peripheral actor via central ones to other more peripheral ones, whereas in a decentralised network, typically several actors have to be bridged until communication reaches the recipient. On the other hand, more complex tasks such as deliberation are typically require rather decentralised networks (Leavitt 1951; Crona and Bodin 2006), owing to the fact that deliberation is hindered by high imbalances of power (and, therefore, of actor centrality).

5 How collective learning changes network structures

Network structure and the quality of relations may not only be conceived as independent variables with respect to collective learning (see above), but also as dependent variables. The question is then how processes of learning change the network structure and the qualities of relations among actors (Knoepfel and Kissling-Näf 1998). While learning is expected to change the knowledge network, this in turn may change the communication network and ultimately change formal roles and collective institutions (see figure 1). To analyse how learning changes network structures, it is important to consider the different subjects of learning (individual and collective) and the forms of learning (single vs. double loop learning) as outlined in table 1.

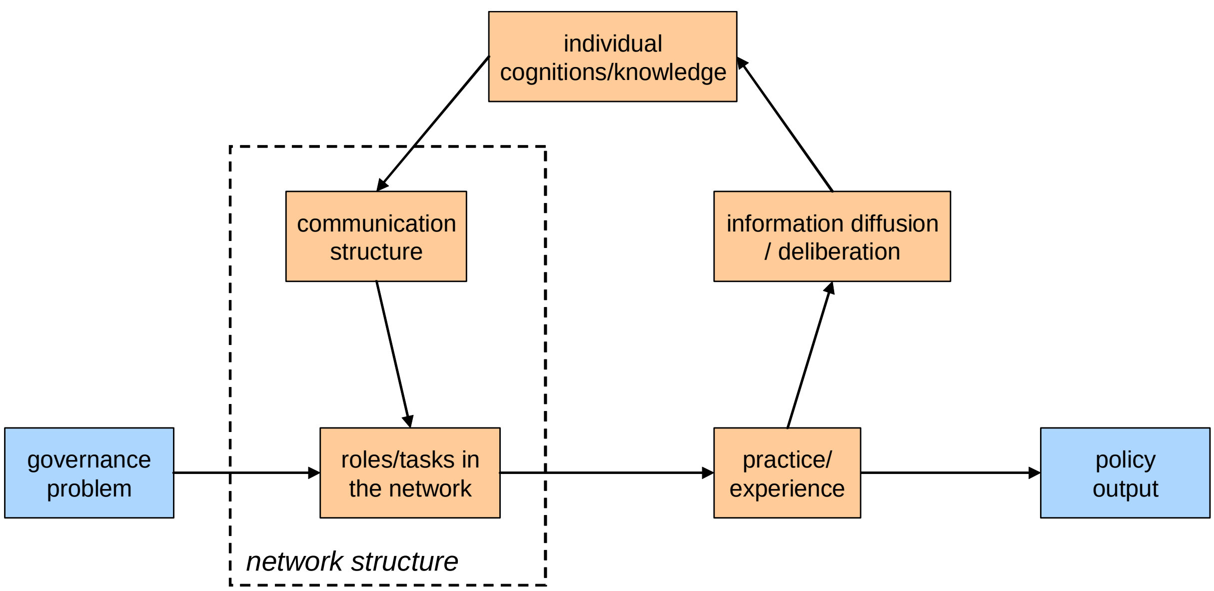

Figure 1: Conceptual model of the role of networks and collective learning for sustainability transitions. Adapted from Newig and Günther 2005.

Single-loop learning is understood as the simple adaptation of actions to a new experience. This is mostly done by individuals or collectively, but based on individual learning. Changes of the network structure due to collective learning mainly involve communication and knowledge transfer among the network members. Collective learning can lead to more intense exchange between actors and hence to increased network density. In addition, the intensity and reciprocity of relations can slightly increase, as well as interactivity within the network.

Changing communication and knowledge transfer structures can also change the roles and tasks of actors within the network. This can also lead to an increase in the degree of centrality for one or more actors and a decrease for others. A change in the centrality of an actor can also affect his/her opinion leadership, in particular if centrality decreases. Regarding the whole network, collective learning processes – such as learning about the competencies of other actors in the network – may lead to higher network centralisation, reflecting a specialised and more efficient communication structure.

The most fundamental changes in networks are caused by double-loop collective learning. Single loop collective learning involves punctual changes in the nature of network relations or their density, but do not change the fundamental network structures. Learning occurs within the chosen paradigm of the network.. Double loop learning, on the other hand, can involve the shift towards new paradigms, i.e. the change of rules of collective choice (Ostrom 1990).

6 Conclusions

In this contribution, we have presented some preliminary thoughts on the mutual relations between network structures and learning in the context of environmental management. It has proven crucial to distinguish between different functions of a network that contribute to collective learning (information transmission, deliberation, resilience). Thus, different network characteristics may be more or less suitable regarding different network functions. While, for example, highly centralised networks may be well suited for the efficient transmission of information, they are less suitable for enabling deliberation and moreover tend to be less resilient to abrupt change. Regarding the network structure as the dependent variable, we have shown that different 'depths' of learning (single- or double-loop) influence network structures in different ways. Ultimately, network structure and learning appear to mutually influence each other, leading to learning cycles that involve both cognitive and institutional factors. They potentially affect the performance of network governance in two ways. Thus, environmental effectiveness can be enhanced by more informed and more creative governance decisions, incorporating a wider variety of knowledge and values, and by better acceptance of decisions by the target actors that participated in network governance, and thus better compliance and implementation.

While we basically believe that relating Social Network Analysis to collective learning and governance issues seems extremely promising, we are well aware of its shortcomings. For network analysis can only provide a static picture of network structures but does not reflect its dynamics. Moreover, social network analysis does not include the learning object (what is learned by the actors) and the consequences for action and behaviour. Whereas Social Network Analysis as such is already highly developed, its conceptual application for learning and governance processes is still at the initial stage, let alone the desideratum of empirical research. We would therefore like to encourage fellow researchers to join our efforts in this promising area of research.

References

Abrahamson, E. and L. Rosenkopf (1997) 'Social Network Effects on the Extent of Innovation Diffusion: A Computer Simulation.' *Organization Science* 8 (3): 289-309.

Argyris, C. (1982) Organizational Dynamics. The Executive Mind and Double-Loop Learning.

Argyris, C. (2003) 'A Life Full of Learning.' *Organization Studies* 24 (7): 1178-92.

Bandura, A. (1977) Origins of behavior, in *Social learning theory*, ed. A. Bandura. New Jersey: Prentice-Hall: 15-55.

Berkes, F. and C. Folke, eds. (1998) *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge: Cambridge University Press.

Bodin, O., B. Crona and H. Ernstson (2006) 'Social Networks in Natural Resource Management: What Is There to Learn from a Structural Perspective? Response to Newman and Dale. 2005. "Network Structure, Diversity, and Proactive Resilience Building: a Response to Tompkins and Adger."' *Ecology and Society* 11 (2): Resp. 2.

Burt, R.S. (1992) *Structural Holes. The Social Structure of Competition* (Cambridge: Harvard University Press).

Castells, M. (1996) *The information age: economy, society and culture, vol. 1: The rise of the network society* (Cambridge, Mass.: Blackwell).

Craps, M. (2003) Social Learning in River Basin Management. Leuven: HarmoniCOP, K.U.Leuven – Centre for Organizational and Personnel Psychology.

Crona, B. and O. Bodin (2006) 'What You Know is Who You Know? Communication Patterns Among Resource Users as a Prerequisite for Co-management.' *Ecology and Society* 11 (2): 7.

Cross, R., T. Laseter, A. Parker and G. Velasquez. (2004) Assessing and Improving Communities of Practice with Organizational Network Analysis. In *The Network Roundtable at the University of Virginia*. Virginia: University of Virginia, Stanford University, Halliburton.

Dedeurwaerdere, T. (2007) The contribution of network governance to sustainability impact assessment, in *Participation for sustainability in trade*, eds. S. Thoyer and B. Martimort-Asso. Aldershot: Ashgate: 209-28.

Diani, M. and D. McAdam, eds. (2003) *Social Movements and Networks: Relational Approaches to Collective Action*. Oxford: Oxford University Press.

Everett, M. and S.P. Borgatti (2005) Extending Centrality, in *Models and Methods in Social Network Analysis*, eds. P.J. Carrington, J. Scott and S. Wasserman. Cambridge et al.: Cambridge University Press: 57-76.

Everett, M.G. and S.P. Borgatti. (1999) Peripheries of Cohesive Subsets. London, Boston.

Fürst, D. (2002) Die Bedeutung von Netzwerken in modernen Gesellschaften, in *Netzwerke und Nachhaltigkeit. Vernetzte Probleme - vernetztes Denken - vernetzte Lösungen. 2. Jahrestagung des Doktoranden-Netzwerks Nachhaltiges Wirtschaften am 13.10.2001*, ed. H. Kanning. Hannover.

Gargiulo, M. and M. Benassi (2000) 'Trapped in Your Own Net? Network Cohesion, Structural Holes, and the Adaptation of Social Capital.' *Organization Science* 11 (2): 183–96.

Gibson, C.C., E. Ostrom and T.-K. Ahn (2000) 'The Concept of Scale and the Human Dimensions of Global Change: a Survey.' *Ecological Economics* 32: 217-39.

Granovetter, M. (1973) 'The Strength of Weak Ties.' *American Journal of Sociology* 78 (6): 1360-80.

Haas, P.M. (2004) 'Addressing the Global Governance Deficit.' *Global Environmental Politics* 4 (4): 1-15.

Habermas, J. (1981) *The Theory of Communicative Action: Reason and the Rationalization of Society (vol. 1)* (Boston: Beacon Press).

Hall, P.A. (1993) 'Policy Paradigms, Social Learning, and the State. The Case of Economic Policymaking in Britain.' *Comparative Politics* 25 (3): 275-96.

Hubacek, K., C. Prell, M. Reed, T. Burt, P. Chapman, S. Cornell, A.J. Dougill, E. Fraser, J. Holden, B. Irvine, N. Jin, M. Kirkby, B. Kunin, C. Quinn, C. Ritsema, V. Jetten, J. Sendzimir, S. Stagl, L. Stringer, M. Taylor, M. Termansen, A. Turner and F. Worrall. (2006) Combining formalised and non-formalised methods to stimulate social learning in resource management. In *Formalised and Non-Formalised Methods in Resource Management*. Osnabrück.

Janis, I.L. (1982) *Groupthink*. 2nd ed (Boston: Houghton Milfin).

Jones, C., W.S. Hesterly and S.P. Borgatti (1997) 'A general theory of network governance: exchange conditions and social mechanisms.' *Academy of Management Review* 22 (4): 911-45.

Kenis, P. and J. Raab. 2003. (Wanted: A Good Network Theory of Policy Making) Paper read at National Public Management Conference, October 9-10, 2003, at Washington, D.C.

Kenis, P. and V. Schneider (1991) Policy Networks and Policy Analysis: Scrutinizing a New Analytical Toolbox, in *Policy Networks. Empirical Evidence and Theoretical Considerations*, eds. B. Marin and R. Mayntz. Frankfurt a.M., Boulder: Campus Verlag, Westview Press: 25-59.

Knoepfel, P. and I. Kissling-Näf (1998) 'Social learning in policy networks.' *Policy & Politics* 26 (3): 343-67.

Latour, B. (1996) 'On actor-network theory.' *Soziale Welt: Zeitschrift für sozialwissenschaftliche Forschung und Praxis* 47: 368-81.

Leavitt, H.J. (1951) 'Some Effects Of Certain Communication Patterns On Group Performance.' *Journal of Abnormal and Social Psychology* 46 (1): 38-50.

Liebeskind, J.P., A.L. Oliver, L. Zucker and M. Brewer (1996) 'Social Networks, Learning, and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms.' *Organization Science* 7 (4): 428.

Marsden, P. (1990) 'Network data and measurement.' *Annual Review of Sociology* 16: 435-63.

Maurel, P. (2003) Public Participation and the Water Framework Directive. Role of Information and Communication Tools.WorkPackage 3 report of the HarmoniCOP project – Harmonising COllaborative Planning. Montpellier.

Messner, D. (1995) *Die Netzwerkgesellschaft. Wirtschaftliche Entwicklung und internationale Wettbewerbsfähigkeit als Probleme gesellschaftlicher Steuerung* (Köln: Weltforum Verlag).

Miller, D. (1996) 'A Preliminary Typology of Organizational Learning: Synthesizing the Literature.' *Journal of Management* 22 (3): 485-505.

Newig, J. and O. Fritsch (2009) 'Environmental Governance: Participatory, Multi-Level – And Effective?' *Environmental Policy and Governance* 19 (3): 197-214.

Newig, J. and D. Günther (2005) 'Network Governance, Social Learning and Sustainability Transitions.' *Paper presented at the Workshop on German-Dutch-Perspectives on Current Issues of Environmental Social Sciences, Münster, 17–18 November 2005. URL: http://www.swome.nl/archive.htm*.

Nicolini, M. and C. Ocenasek (1998) Environmental Impact Assessment with Public Participation: The Case of a Proposed Landfill Site in the Austrian Pinzgau, in *Alternative Dispute Resolution in Environmental Conflicts. Experiences in 12 Countries*, ed. H. Weidner. Berlin: Edition Sigma: 330-39.

O'Toole Jr., L.J., K.I. Hanf and P.L. Hupe (1999) Managing Implementation Processes in Networks, in *Managing Complex Networks. Strategies for the Public Sector*, eds. W.J.M. Kickert, E.-H. Klijn and J.F.M. Koppenjan. London, Thousand Oaks, New Delhi: Sage Publications: 137-51.

Ostrom, E. (1990) *Governing the Commons. The Evolution of Institutions for Collective Action*, *Political Economy of Institutions and Decisions* (Cambridge et al.: Cambridge University Press).

Ostrom, E. (2001) Decentralization and development: the new Panacea, in *Challenges to Democracy: Ideas, Involvement and Institutions*, ed. K. Dowding. Basingstoke, u.a.: Plagrave.

Pahl-Wostl, C. (2002) 'Towards sustainability in the water sector - The importance of human actors and processes of social learning.' *Aquatic Sciences* 64: 394–411.

Pahl-Wostl, C. (in press) 'A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes.' *Global Environmental Change*.

Pahl-Wostl, C., M. Craps, A. Dewulf, E. Mostert, D. Tabara and T. Taillieu (2007) 'Social learning and water resources management.' *Ecology and Society* 12 (2): -.

Prell, C., K. Hubacek and M. Reed (2009) 'Stakeholder Analysis and Social Network Analysis in Natural Resource Management.' *Society & Natural Resources* 22: 501-18.

Provan, K.G. and P. Kenis (2007) 'Modes of Network Governance: Structure, Management, and Effectiveness.' *Journal of Public Administration Research and Theory* 18: 229–52.

Raab, J. and P. Kenis (2007) Taking Stock of Policy Networks: Do They Matter?, in *Handbook of Public Policy Analysis: Theory, Politics, and Methods*, eds. F. Fischer, G. Miller and M. Sidney. Boca Raton, London, New York: CRC Press: 187-200.

Reinicke, W.H. and F. Denkg (2000) *Critical choices: The United Nations, Networks and the Future of Global Governance* (Ottawa: Int Development Research Council).

Rogers, E.M. (1995) *Diffusion of innovations*. 4th ed (New York: Free Press).

Sabatier, P.A. (1988) 'An advocay coalition framework of policy change and the role of policyoriented learning therein.' *Policy Sciences* 21: 129-68.

Scharpf, F.W. (1997) *Games Real Actors Play. Actor-Centered Institutionalism in Policy Research* (Boulder, CO: Westview Press).

Schusler, T.M., D.J. Decker and M.J. Pfeffer (2003) 'Social Learning for Collaborative Natural Resource Management.' *Society and Natural Resources* (15): 309-26.

Schweitzer, T. (1988) Netzwerkanalyse als moderne Strukturanalyse, in *Netzwerkanalyse: ethnologische Perspektiven*, ed. T. Schweitzer. Berlin: Riemer.

Scott, J. (2003) *Social network analysis: a handbook* (London: SAGE).

Siebenhüner, B. and J. Suplie (2005) 'Implementing the access and benefit-sharing provisions of the CBD: A case for institutional learning.' *Ecological Economics* 53: 507– 22.

Swieringa, J. and A. Wierdsma (1992) *Becoming a learning organization* (Reading, Mass.: Addison Wesley).

Tichy, N., M. Tushman and C. Fombrun (1979) 'Social network analysis for organisations.' *The Academy of Management Review* 4 (4): 507-19.

Tippett, J., B. Searle, C. Pahl-Wostl and Y. Rees (2005) 'Social learning in public participation in river basin management--early findings from HarmoniCOP European case studies.' *Environmental Science & Policy* 8 (3): 287-99.

Torfing, J. (2005) 'Governance network theory: towards a second generation.' *European Political Science* 4: 305-15.

Valente, T.W. (2005) Network Models and Methods for Studying the Diffusion of Innovations, in *Models and Methods in Social Network Analysis*, eds. P.J. Carrington, J. Scott and S. Wasserman. Cambridge et al.: Cambridge University Press: 98-116.

Wasserman, S. and K. Faust (1999) *Social Network analysis: methods and applications* (Cambridge: Cambridge Univ. Press).