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Research, part of a Special Feature on Social Network Analysis in Natural Resource Governance

Synapses in the Network: Learning in Governance Networks in the Context of Environmental Management

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

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. The key issue approached here is the mutual relations between network structure and learning, with the aim of improving environmental management. Up to now, there have been few attempts to apply social network analysis (SNA) to learning and governance issues. Moreover, little research exists that draws on structural characteristics of networks as a whole, as opposed to actor-related network measures. Given the ambiguities of the concepts at stake, we begin by explicating our understanding of both networks and learning. In doing so, we identify the pertinent challenge of individual as opposed to collective actors that make up a governance network. We introduce three 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, centralization, or the occurrence of weak as opposed to strong ties. (2) How does collective learning alter network structures? We conclude by outlining a number of open issues for further research.

Key Words: *collaboration; collective learning; deliberation; effectiveness; information diffusion; network governance; network resilience; social network analysis*

INTRODUCTION

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 as an attempt to integrate different state and nonstate actors and their respective expertise is increasingly being proposed to cope with sustainability problems (Dedeurwaerdere 2007, Voß et al. 2007). With its roots in the economic (Jones et al. 1997) and policy networks literature (Kenis and Schneider 1991, Scharpf 1997, O’Toole Jr. et al. 1999, Haas 2004, Torfing 2005), network governance is an emerging concept that has not yet been consolidated.

One main reason for the proliferation of network approaches in environmental management is their potential to integrate and make available different sources of knowledge and competences and to foster individual and collective learning (Liebeskind et al. 1996, Wenger 2000, Haas 2004, Dedeurwaerdere 2007). Current environmental management typically faces complex problem settings characterized by uncertain and unpredictable systems dynamics, a lack of knowledge on the effects of interventions, and societal conflicts about the appropriateness of interventions (Newig et al. 2008). Notably, the literature on complex social–ecological systems (Gunderson and Holling 2002, Berkes et al. 2003) has pointed out that closely coupled systems components, feedback, nonlinearity, and self-organization typically lead to emergent dynamics and unpredictable systems behavior.

Against this background, learning becomes a central category in governance approaches (Knoepfel and Kissling-Näf 1998, Siebenhüner and Suplie 2005).

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First of all, learning is required to understand and cope with the dynamics of social–ecological systems and the possibilities and limitations of their management; different sources of knowledge can aid in this. In certain settings, lay (local) knowledge can also play an important role. Moreover, and presumably even more important for governance, learning can generate “knowledge about facts, values, problems and opportunities, areas of agreement and disagreement, alternative actions, possibilities for working together” (Schusler et al. 2003:317). Involving different sources of knowledge and expertise in environmental governance can be done in different forms of participatory governance and collaborative management. We speak of governance networks only when these forms of involvement go beyond an ad hoc basis and become formally or informally institutionalized.

Network-governance 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 (Head 2008). Of course, networks differ in size, composition, intensity of communication, density, and other structural properties. Therefore, we can generalize the above hypothesis as follows:

> The structural properties of a governance network (such as size, composition, density, and so forth) 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 (see Granovetter 1982, Burt 2000, or Carlsson 2000 as notable exceptions. However, these approaches rely more on heuristic notions of networks rather than precise network properties as developed in the social network analysis literature). This stands in stark contrast to the wealth of publications on the impact of single actors or actor groups “within” networks on certain outcomes such as resource management decisions (see, for example, Bulkeley 2005, Compston 2009). Regarding the reasons for the widespread focus on within-network structures as opposed to a whole-network perspective, Provan and Kenis (2007) speculate that “developing a deep understanding of network governance requires collection of data on multiple networks, which can be time consuming and costly” (Provan and Kenis 2007:230). 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 is a perspective emerging in which network structure is considered as an independent variable (Christopoulos 2008, Prell et al. 2009).

A rich and most useful toolbox for analyzing network structure has been developed in the field of social network analysis (SNA). Among others, SNA provides mathematical measures of whole networks. For instance, the density of a network, that is, the number of actual ties in a network divided by the number of possible ties, could play a crucial role for different aspects of learning. 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, although it does acknowledge the role of networks, has hardly made use of SNA (Prell et al. 2008).

We aim to bridge this gap and make a first attempt toward integrating the collective learning and network governance literature with SNA approaches. This allows a sharpening of the concept of learning in networks by way of employing formal SNA measures, and formulation of hypotheses on the relation of network properties with learning. We begin by explicating our understanding of governance networks in environmental management. We then define different forms of learning in networks. Subsequently, we address these 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? To this end, we integrate theoretical assumptions from network theory, social learning, and complex systems. We conclude by outlining pathways for further research.

GOVERNANCE NETWORKS

Here, we define our notion of governance networks and review potential benefits for environmental management, and discuss two challenging issues in the definition of a governance network: its boundaries and the notion of network “actor.”

Governance networks have been defined by Torfing as:

> *(1) relatively stable horizontal articulations of interdependent, but operationally autonomous actors who (2) interact with one another ... (3) within a regulative, normative, [and cognitive] ... framework that is (4) self-regulating within limits set by external forces and which (5) contributes to the production of public purpose.* (2005:307)

From this definition, three aspects are particularly worthwhile noting in the present context. First, the "relative stability" of governance networks distinguishes them from more spontaneous, fluid, and ephemeral forms of coordination. For instance, temporary forms of participatory governance such as planning cells or round tables, exhibit similar characteristics as governance networks, but lack their relative stability. Therefore, the development of mutual trust, reciprocal relationships, and a well-attuned cooperation is more likely to be found in governance networks (Koppenjan 2008). Although networks may and do change over time (see, for example, Wellman and Berkowitz 1988, Snijders et al. 2010), they can be described as institutionalized relations. Second, networks have a cognitive dimension that involves information transmission and learning processes. Third, governance networks are related to public purposes such as the collective management of natural resources, 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 (Kickert et al. 1999, Dedeurwaerdere 2007), but this need not be the case. Having thus defined governance networks, we speak of network governance as those governance processes that draw on networks as a relatively stable form of coordination.

The advantages of networks as structures at the so-called "mesolevel" between market and hierarchy (see Scharpf 1997), which incorporates different knowledge sources and competencies, led to an uptake of networks as a governance approach in the mid 1990s (for an overview, see, for example, Ostrom 2001, Diani and McAdam 2003, and Haas 2004). 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). One particular form of networks important to governance problems is "epistemic communities," in which actors share the same basic causal beliefs and normative values (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 consensus building and the development of cognitive commodities.

Environmental management currently faces enormous challenges, many of which relate to the complexities and uncertainties inherent to environmental and sustainability problems. In particular, uncertainties regarding the functioning of complex social–environmental systems, as well as implementation problems because of highly distributed power structures (Newig et al. 2008). Network governance can provide a means to address both of these governance problems by institutionalizing learning on facts and deliberation on value judgments (Head 2008). This can be demonstrated by the example of transnational bureaucracy networks in the realm of global chemicals safety, which have been analyzed by Warning (2006). Chemicals, such as persistent organic pollutants, constitute a truly global environmental problem, for:

> *[They] travel through the atmosphere and accumulate far away from the countries where they are deliberately released as pesticides...The problems caused by the transboundary effects of chemicals are increased by the knowledge gap aptly dubbed "Toxic Ignorance": the intrinsic properties of more than 100,000 substances are unknown—and the knowledge cannot be generated by one state alone. (Warning 2006:323)*

Not unlike an epistemic community, transnational networks have formed around initiatives by international organizations and successfully developed rules for addressing global chemicals issues, many of which have been implemented by national legislations. Shared professional norms, and a joint interest in problem solving, rather than identical interests, have fostered the formation of these networks. Within these structures, a wealth of knowledge on environmental cause-and-effect relations as well as on the societal acceptability of certain norms was brought together, enabling a thorough deliberative process involving societal learning, arguing, and bargaining. "Networks cross-cut the public and the private sphere, allowing industry and non-economic NGOs to participate in the deliberations" (Warning 2006:323). Most importantly, these transnational networks made it possible to circumvent the institutional inertia that is typically found in political settings with many actors of divergent interests, most notably on a global level.

Other examples include very local issues with site-specific knowledge such as the compliance problem of reducing agricultural nitrates in groundwater in northwest Germany (Kastens and Newig 2008). Here, governance networks among water companies, agriculture, administration, and later environmental NGOs have been successful in reducing agricultural nitrate loads. As an ongoing process, these state-initiated governance networks have been operating since 1982. In a region of intensive livestock farming, nitrate loads attributed to the spread of liquid manure could be reduced by the joint elaboration of site-specific measures of land management involving the development of new solutions, but also bargaining and financial compensation measures. Thus, sectoral integration proved to be a central element of successful network governance.

Whereas governance networks have been successful in environmental management both on a global and local level, they are also recommended for improving interplay between different levels of governance (Warning 2006, Newig and Fritsch 2009*a*). In the words of Peter Haas:

> *The best institutional structure for dealing with complex and uncertain policy environments is loose, decentralized, dense networks of institutions and actors that are able to quickly relay information, and provide sufficient redundancies in the performance of functions so that the elimination or inactivity by one institution does not jeopardize the entire network. Decentralized "information-rich" systems are the best design for addressing highly complex and tightly-coupled problems. In short, strong centralized institutions are fundamentally unecological. They run counter to the ecological principle of requisite diversity or flexibility; inhibit random mutation, or policy innovation; and are easily captured by single powerful parties.* (2004:7, emphasis added).

Governance networks, as defined above, are a theoretical construct that relates to an empirical phenomenon. Two key challenges arise when trying to match both.

First, the delimitation of the "network boundary," i.e., the set of actors that define the network, is not without difficulty. Social networks in general, and governance networks in particular, may—but need not—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 organizational membership or geographical location determine who belongs and who does not belong to a network. Alternatively, the network boundary may be defined by a certain threshold frequency of interaction, or intensity of ties, among network members as opposed to nonmembers (Wasserman and Faust 1999:31). For our purposes, we define governance networks by those members who commit themselves to the governance task at hand (Knoepfel and Kissling-Näf 1998). This allows us to determine a fixed set of actors. Empirically, actors in a given governance network will either be defined by as those meeting regularly as a group, or by those who are regarded by the majority as members of the network, that is, a "realist" approach (Wasserman and Faust 1999).

Second, and more critically, "who" the actors are in a network is by no means trivial. Although parts of social network theory (e.g., research on weak and strong ties) assume individual persons as network members, governance networks are typically perceived to be made up of corporate or collective actors such as administrative or business organizations, or citizens' initiatives (Kenis and Schneider 1991, Torfing 2005). In existing research, this problem is often circumvented by simply equating one with another: it is assumed that individual persons, who actually communicate, build trust, learn, etc., represent the interests and perceptions of their respective organization. However, this assumption is not unproblematic: First of all, individual people need not necessarily identify completely with the interests of their respective organization and act accordingly. In the realm of environmental management in particular, public officials tend to have "greener" values than those officially proclaimed by their administrative body. Second, the person(s) representing an organization in a governance network may change. It is not uncommon that people who participate in network meetings are frequently replaced by others, making it much more difficult to build trust and enable collective learning. For the sake of analytical clarity, we assume here that network actors are individual persons, albeit typically members of an organization or other collective entity, who mainly act in the role of representing their constituency.

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" (Castells 1996). In his impressive work, Castells argues that global networks are heavily on the increase 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, Latour's (1996) "actor network theory" (ANT) has gained popularity, especially in sociology. As Latour explicitly incorporates nonhuman actors ("actants") in his approach, the study of governance networks can hardly profit from these ideas.

INDIVIDUAL AND COLLECTIVE LEARNING IN NETWORKS

We shall review why learning is an essential element of network governance in the context of environmental management. We shall 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 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 "deeper," applying the concept of single-loop and double-loop learning to learning in networks.

Learning in Governance Networks for Environmental Management

One of the main reasons why governance networks are regarded as a more effective means of governance, as opposed to purely hierarchical or market-based governance, is its potential to foster learning both on an individual and on a collective level (Schusler et al. 2003). As discussed, two aspects are crucial for environmental management. First, the frequent knowledge gaps regarding complex social–ecological issues call for an integration of different kinds of expertise as provided by a larger number of actors, often state and private. The above examples of global chemical safety and local agricultural nitrate reduction illustrate this. This may involve joint learning about the dynamics of complex systems (Pahl-Wostl and Hare 2004), and also the inclusion of local professional or lay knowledge not available to science and administration. One revealing example of the latter is that of bovine spongiform encephalopathy (BSE) spread through conditions of cattle breeding. "Regulations demanding the removal from cattle carcasses of potentially hazardous body parts (such as the spinal cord) made assumptions about the conditions of work in slaughterhouses, conditions that inspectors found it impossible practically to ensure" (Yearley 2000:106). Second, a complex mix of different, and often conflicting, societal values and interests regarding the governance issue at stake calls for effective means of communication to resolve conflicts or even develop shared views through deliberative processes. In summary, both information transmission and deliberation are central elements of learning that can be provided through governance networks.

Learning

Defined widely, learning refers to cognitive changes (Miller 1996). In a stricter sense, learning involves not only cognitive but also behavioral change. That is, only when cognitive change manifests in changed action, can one speak of learning (Argyris 2003). Here, 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. Although learning can involve all sorts of dimensions, 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 and knowledge generation. 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 communication with other network members. These also exert influence on information processing, e.g., by copying from others (Bandura 1977) 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 to foster learning: information transmission and deliberation (Newig and Günther 2005):

- Information transmission: Through the interaction and communication of actors, knowledge and information can be transmitted among the actors (information distribution or diffusion, see, for example, Valente 2005). This is a first prerequisite of the (collective) learning of actor groups. Actors gain access to relevant information and other participants' 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; that is, network resilience.

- Resilience: Drawing on the concept of resilience as developed in the social–ecological systems literature (Berkes and Folke 1998), we define network resilience as the capacity of a network to remain intact in its basic functions when subject to pressure or sudden change. For instance, if an important actor in a small, nonredundant network structure suddenly disappears (e.g., by leaving the network or because of illness or death), the whole network might encounter 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 their learning-related functions.

Collective Learning: Change of Synapses in a Social Network

Learning on an individual level involves changes in cognitive structures of individual brains. Collective 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 through having experiences oneself. For our purposes, this type of learning would still be considered individual learning, because 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, in the sense of Swieringa and Wierdsma (1992), refers to a change of shared mental models among members of an organization, group, or network. Collective learning often implies that social structure changes. In line with much structuralist thinking in sociology, we define social structure very generally as stable patterns within society on a supra-individual (emergent) level. Social structure comprises both "institutional structure," that is, institutions in the broadest sense refer to informal or formal norms—such as collective decisions—that shape individual action, and "relational structure," that is, relations between actors such as networks (López and Scott 2000). Thus, we do not limit the concept of social structure to that of social networks (as, for instance, Wellman and Berkowitz 1988 do). Regarding relational structure, we can take up the analogy of individual learning as a change in cognitive structures (links of neurons in a brain), where collective learning in a network can be regarded as a change of synapses (links) in a social network.

Collective learning in governance networks bears similarities to policy learning, as conceptualized, for example, by Sabatier 1988. Policy-oriented learning refers to “relatively enduring alterations of thought or behavioral 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” can be attributed to learning! Regularly, policy change occurs merely because of (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 that concerns the underlying values, beliefs, and attitudes of the actors (group). Hence, it is necessary to disaggregate learning and conceptually distinguish among different forms of learning. Argyris (1982) developed the concept of single-loop and double-loop learning, which is valuable in this context. 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 between desired goals and the achieved results of an action, which is corrected without changing the underlying values, but remains within the accepted routines. However, in double-loop learning, 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).

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 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 2009). 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 because the effect of social closure and group thinking is likely to hinder actors from reflecting on goals, norms, and rules. Double-loop learning processes, i.e., paradigm shifts, are more likely to occur in the (re-)formation phase of a network (Pahl-Wostl 2009). 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.

NETWORK CHARACTERISTICS FOSTERING LEARNING

We will now examine the impact of network structure on the potential for learning. Social science research has developed a wide range of instruments to describe and evaluate network characteristics. To analyze networks in a standardized and formalized manner, methods developed within SNA (Wasserman and Faust 1999, Scott 2000) have advanced and become rather elaborate. Social network analysis provides numerous definitions and mathematical tools, derived from graph theory, that allow for a stringent description and analysis of network structures.

We will discuss the potential effect of well-defined, structural whole-network measures. These comprise average homophily and multiplexity in a network, the relation of weak to strong ties, network size, density, cohesion (absence of structural holes), and centralization. Drawing on different sets of literature, that is, network theory, social learning, and complex systems research, we present a number of hypotheses on the suggested effects of these characteristics on the three learning-related functions of governance networks, that is, information distribution, deliberation, and resilience, and to the single-loop and double-loop learning. Table 2 provides an overview of these hypotheses.

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

	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 Collective decisions: change of rules of operational choice	Fundamental change in network structure; building of network resilience Collective decisions: change of rules of collective choice

Nature of Network Ties: Average Homophily and Multiplexity; Weak as Opposed to Strong Ties

Ties among actors in a governance network can be characterized in different ways. There is reason to assume that the overall nature of relations in a network affects the network's potential to foster or inhibit the different forms of learning.

- Average homophily: Human communication theory states that, in principle, the distribution of knowledge and flow of ideas mostly occurs among 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 average homophily among actors is supposed to distribute information and (tacit) knowledge more quickly, i.e., the actors have a better source for learning (Powell 1990, Cross et al. 2001). However, for a paradigm shift in the sense of double-loop learning, this is not that clear. Effective information and knowledge distribution is needed here too. Yet homophilous actors also tend to close their perceptions to outside information (Krackhardt and Stern 1988), thus strengthening confirmation bias of individuals in the network.
- Average multiplexity: Network relations can be of different types. Multiplexity arises when ties of multiple types link the same actors (Koehly and Pattison 2005). For instance, members of a governance network can communicate about an environmental-management problem at stake, have a formal hierarchical relationship, or be friends with one another. Moreover, multiplexity can arise through different arenas in which actors are engaged. Examples are: support networks, coworkers, exchange networks, etc. (Tichy et al. 1979). In all of these, communication plays an important role. Generally, multiplexity of network ties is expected to support information diffusion. "Thus the breadth of someone's links might serve to provide an individual with a variety of information sources" (Hartman and Johnson 1989:529).

Although they are different concepts, homophily and multiplexity are not wholly independent, for homophily is likely to lead to multiplex relations. To support learning, relations in a network should generally be characterized by a high degree of homophily and multiplexity. These are the basis of trust among the actors, which is needed to develop a learning-supported environment (Liebeskind et al. 1996, Booher and Innes 2002). However, high values in these characteristics can also indicate a cognitive blocking situation that does not allow double-loop learning and, hence, radical changes or paradigm shifts.

Table 2. Hypothesised influence of network characteristics on the performance of network functions.

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

(+) = high (low) values in the independent variable lead to high (low) values in the dependent variable.

(–) = vice versa.

(º) = no discernible, or unclear, influence.

- Weak and strong ties: The strength of a network tie has been defined as a “combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services that characterize the tie” (Granovetter 1973:1361). Typically, weak ties are less redundant and more flexible than strong ties, they can bridge longer distances within a network and, thus, provide new information and knowledge for the network. Moreover, weak ties can link network members with actors outside the boundaries of the network. However, because of the loose link, weak ties are less suitable for creating trust, shared values, and norms. Conversely, deliberative processes with intensive exchange of arguments tend to work better with strong ties that are mainly based on the bilateral trust of actors to respect the mutual normative frameworks, facilitating the development of collective action routines (Ostrom 1990). On the other hand, a high level of trust among actors could lead to a

> closed common worldview of the actors and an overall inflexibility and “cognitive blocking” (Messner 1995) and an attitude of nonlearning. This social closure has been termed “groupthink.” “The more amiability and esprit de corps among members of a policy-making ingroup, the greater is the danger that independent critical thinking will be replaced by groupthink” (Janis 1982:198). Radical changes and paradigm shifts can hardly be implemented in these networks. However, based on research on organizational networks, Kraatz (1998) argues that the information-sharing power of strong ties outweighs the above arguments even for adapting to severe external threats.

Taking up arguments from complex systems theory (Gibson et al. 2000, Newig and Fritsch 2009*a*), 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 in different respects. Findings from an environmental-governance network in Helsinki support these assertions (Toikka 2009).

Network Size, Density, and Cohesion

“Network size” is defined by the number of actors in a 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. If the whole network is involved, 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 also occur within a larger network. This requires analysis of cohesive subgroups (Everett and Borgatti 1999). Generally, larger networks are likely to exhibit stronger resilience as, for example, the exit of actors or the termination of relations can more easily be replaced by others in the network.

“Network density” is defined as the number of relations in a network divided by the maximum possible number of relations. Typically, network density is also a function of network size: given a maximum number of ties an actor can maintain, larger networks will likely be less dense than smaller ones because of the quadratically growing number of possible relations (Scott 2000). 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). As well, deliberation 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 high cohesion, i.e., the absence of structural holes in a network (Gargiulo and Benassi 2000). On the other hand, very dense and strongly cohesive networks tend to be less able to adapt to fundamental change, e.g., restructuring the network (double-loop learning; Burt 1992, Gargiulo and Benassi 2000) because they tend to be “trapped” in their own groupthink. Structural 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 thus promote innovation and learning.

Network Centralization

“Network centralization” is a measure of how “uneven” centrality is distributed in a network (Scott 2000). 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 as a “local” measure of centrality is defined by the number of directly related actors in a network; closeness centrality is a measure of how easily an actor can reach any other actor in a network by relying of shortest distances in the network graph. Typically, centralization 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 centralized 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 opinion leadership leaves the process (Nicolini and Ocenasek 1998).

Information transmission is typically easier in centralized, as opposed to decentralized, networks (Leavitt 1951, Crona and Bodin 2006). Given a similarly dense network, a more centralized one will allow information to flow quickly from, for example, a peripheral actor through central ones to other more peripheral ones, whereas in a decentralized network, typically several actors have to be bridged until communication reaches the recipient. On the other hand, more complex tasks such as deliberation typically require rather decentralized 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).

HOW COLLECTIVE LEARNING CHANGES NETWORK STRUCTURES

Network structure and the quality of relations may not only be conceived of as independent variables with respect to collective learning, 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). Whereas 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 analyze how learning changes network structures, it is important to consider the different subjects of learning (individual and collective) and the forms of learning (single- or double-loop learning) as outlined in Table 1.

Single-loop learning is understood as the simple adaptation of actions to a new experience. This is primarily done by individuals or collectively, but is based on individual learning. Changes in network structure attributed to collective learning primarily 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 can 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 centralization, reflecting a specialized and more efficient communication structure.

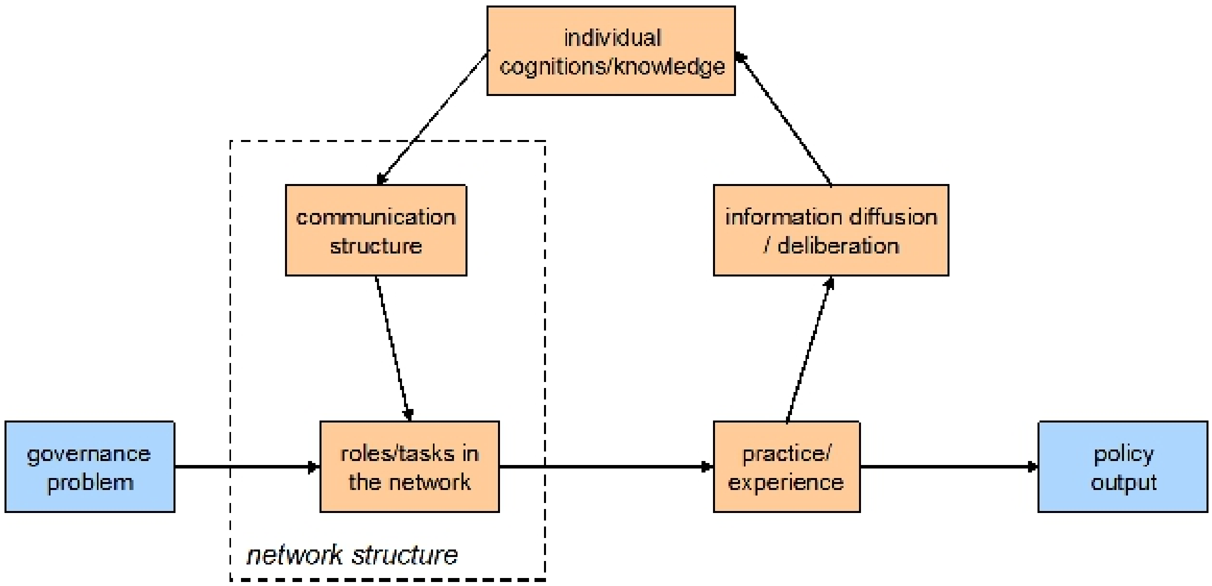
The most fundamental changes in networks are caused by double-loop collective learning. Single-loop collective learning involves punctual changes in the nature of network relations or their density, but does not change fundamental network structures. Learning occurs within the chosen paradigm of the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

CONCLUSIONS

Here, we have presented some preliminary thoughts on the relationship between the structure of governance networks and learning in the context of environmental management. Unlike in most previous research, and taking up recent calls from, for example, Provan and Kenis 2007, Christopoulos 2008, and Prell et al. 2009, we have employed SNA to specify network concepts and focused on whole-network measures as structural variables.

As learning concepts in the literature are quite diverse (e.g., social learning), we have specified learning in networks by introducing three different learning-related functions of a network, namely information transmission, deliberation, and resilience. Thus, we reveal that certain network characteristics, such as density, centralization, or the relation of weak to strong ties, can have different learning-related effects, depending on whether they relate to information transmission or deliberation. Whereas, for example, highly centralized 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

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



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, leading to better compliance and implementation.

Reflecting on these initial attempts at conceptualizing learning in governance networks in the context of environmental management with the means of SNA, we see two major challenges to be addressed through further research. We have already addressed the question of who constitutes an actor in governance networks. The pertinent literature has not resolved this issue in a satisfactory manner. Existing research tends to be ambiguous about, mix up, or equate, organizations with individuals, the latter supposedly representing the former. Our approach of confining the governance-network concept to individual actors is certainly feasible, both conceptually and empirically. However, this contrasts with the common usage in policy and governance-networks literature that assumes actors in policy or governance networks to be collective. More research is clearly needed on how this link between individual and collective actors can be conceptualized, in particular with regard to SNA.

Large parts of the hypotheses presented here have not been tested empirically. Although many of the scholarly works we draw on do rely on empirical research, only some relate to governance networks, let alone those operating in an environmental management context. We propose to adapt the case-survey method (Larsson 1993, Newig and Fritsch 2009*b*) to the growing body of empirical network case studies. This will allow the systematic comparison and integration of partial insights on the relation of network structure on learning aspects in the context of environmental management.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol15/iss4/art24/responses/

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