Rogers, K. H., R. Luton, H. Biggs, R. Biggs, S. Blignaut, A. G. Choles, C. G. Palmer, and P. Tangwe. 2013. Fostering complexity thinking in action research for change in social–ecological systems. *Ecology and Society* **18**(2): 31. http://dx.doi.org/10.5751/ES-05330-180231

Research, part of a Special Feature on Applied Research for Enhancing Human Well-Being and Environmental Stewardship: Using Complexity Thinking in Southern Africa

Fostering Complexity Thinking in Action Research for Change in Social–Ecological Systems

Kevin H. Rogers [1], *Rebecca Luton* [1], *Harry Biggs* [2], *Reinette (Oonsie) Biggs* [3], *Sonja Blignaut* [4], *Aiden G. Choles* [4], *Carolyn G. Palmer* [5] *and Pius Tangwe* [6]

ABSTRACT. Complexity thinking is increasingly being embraced by a wide range of academics and professionals as imperative for dealing with today's pressing social–ecological challenges. In this context, action researchers partner directly with stakeholders (communities, governance institutions, and work resource managers, etc.) to embed a complexity frame of reference for decision making. In doing so, both researchers and stakeholders must strive to internalize not only "intellectual complexity" (knowing) but also "lived complexity" (being and practicing). Four common conceptualizations of learning (explicit/tacit knowledge framework; unlearning selective exposure; conscious/competence learning matrix; and model of learning loops) are integrated to provide a new framework that describes how learning takes place in complex systems. Deep reflection leading to transformational learning is required to foster the changes in mindset and behaviors needed to adopt a complexity frame of reference. We then present three broad frames of mind (openness, situational awareness, and a healthy respect for the restraint/action paradox), which each encompass a set of habits of mind, to create a useful framework that allows one to unlearn reductionist habits while adopting and embedding those more conducive to working in complex systems. Habits of mind provide useful heuristic tools to guide researchers and stakeholders through processes of participative planning and adaptive decision making in complex social–ecological systems.

Key Words: *competency; complexity thinking; consciousness; habits of mind; integrated learning framework; lived complexity; reductionism; tacit knowledge; unlearning*

INTRODUCTION

As the world around us becomes more complex, our understanding of how to behave in it is changing fast, fundamentally, and with major consequences for our approaches to addressing present-day problems. Most researchers of social–ecological systems recognize the paradigm shift accompanying the advancing wave of complexity thinking that emphasizes nonlinear, context-, and contingency-specific interactions among emergent entities. Complexity thinkers eschew, to greater or lesser extents, traditional reductive thinking that assumes linearity in causal interactions between independent entities, but to what extent does the complexity "movement" go beyond this narrow frame of reference and what are the implications for embedding complexity thinking in the management of social–ecological systems?

The discourse on complexity can be found in the literature of many academic and professional disciplines (Urry 2005), from business (Ostrom 2002, Snowden and Boone 2007) to philosophy (Cilliers 1999, Ulanowicz 2009), education (Grimmet et al. 1990), economics (Ostrom 1990, 2002, Scharmer 2010), health (Zimmerman 1999, Jayasinghe 2011), leadership (Wheatley 2006), the natural and social sciences (Kay et al. 1999, Levin 1998, Holling and Allen 2001, Funtowicz and Ravetz 1992, Nowotny et al. 2001, Mazzocchi 2008, Ulanowicz 2009), planning and policy (Mitchell 2009), public service (Raelin 2001), and warfare and crime (Ward 2005, Habtemichael and Cloete 2010). Strong discipline and cross-discipline peer groups now debate, embrace, and advocate complexity thinking as imperative to understanding and dealing with the pressing social–ecological challenges of the day. However, most of the literature, especially the academic literature, is about what the complexity philosopher Edgar Morin (2008) would call "intellectual complexity" and much less about "lived complexity," which together provide a social ecology of knowledge and being, respectively (Montouri 2008). Morin goes on to assert that "Scientists who do not practically master the consequences of their discoveries, do not control the meaning and nature of their research, even on an intellectual level" (Morin 2008:4). In other words, real or full understanding, including that of complexity, can only come from an internalized intersection of understanding (intellectual) and practicing (lived).

This duality of knowing and being has important implications for the study of social–ecological systems under a complexity frame of reference (sets of assumptions and expectations that bound meaning, our mindsets, perspectives, and habits of mind (Mezirow 2003). In these early times of complexity thinking, it is likely that many have yet to internalize it, and intellectual complexity probably dominates over lived complexity. The

[1]Centre for Water in the Environment, University of the Witwatersrand, [2]South African National Parks, [3]Stockholm Resilience Centre, [4]The Narrative Lab, Johannesburg, [5]Unilever Centre for Environmental Water Quality Institute for Water Research, Rodes University, [6]Department of Social Work / Social Development University of Fort Hare

understanding that emerges is likely to be quite different for the two. When complexity thinking is used as a frame of reference for the interpretation of the results of case studies of social–ecological systems, there may be little need to distinguish between the two forms. However, the growing awareness of the need to adopt a postnormal (Funtowicz and Ravetz 1992) or mode 2 (Nowotny et al. 2001) approach to "science in the service of society" (Rogers and Breen 2003) is more and more encouraging action research approaches that require researchers and their stakeholder partners to "live" complexity as a new paradigm for decision making in communities and institutions.

The difference between "case study" and "action" research is important in this context. Case studies are well established as a means for researchers to gain a better understanding of how other people experience and respond to real-life situations. Despite the fact that case studies are very context dependent, the research process advocated in the literature (Stake et al. 2005, Simons 2009, Yin 2009) is one in which the researchers first define the research questions they wish to address and then seek cases in order to generate an empirically based understanding.

Action research (Hart and Bond 1995, Hult and Lennung 2007) is different because researchers and stakeholders design the research cooperatively and face to face. Their aim is to define a desired future and undertake well-informed actions that will expand their knowledge, enhance their competencies, and overcome challenges for moving to that future. Action research is, therefore, very much a process of generating personal and institutional change (Reason and Bradbury 2007) and with it comes the need for deep trust between all parties. That trust will not emerge if the parties themselves do not adopt a common frame of reference for decision making and "walking-the-talk" along the path that takes them forward. The researchers must practice what they preach if they are not to "mutilate knowledge and disfigure reality" as Morin (2008:3), somewhat belligerently but cogently, phrases it.

How then do action researchers practice the complexity thinking they want to share with the other participants (stakeholders)? Many would brush this off as a simple matter of knowledge transfer (Roux et al. 2006) from researchers to users and stakeholders. Write a guide and give it to them to read! In action research, however, both researchers and stakeholders must actively engage new knowledge and its attendant behaviors if they are to transform their decision-making styles and skills.

Three main challenges arise for action research in this context. Firstly, both researchers and stakeholders must be conscious of their current frames of reference and how they are located within reductionist or complexity paradigms. Secondly, the process of assimilating and internalizing new knowledge to the extent that it transforms world views is itself complex, and an intellectual acceptance of the characteristics of complex systems is only the foundation on which to start building a new set of thinking patterns and behaviors. In this paper, we first contrast reductionist and complexity thinking as a basis for people to become conscious of their own thinking patterns and then propose an integrated framework for how learning can lead to transformation of a person's frame of reference in complex systems. Lastly, we explore a number of habits of mind that may be used as heuristic tools through which researchers and stakeholders can begin to "live" complexity.

BECOMING CONSCIOUS OF REDUCTIONIST AND COMPLEXITY FRAMES OF REFERENCE

The literature contains a number of discussions contrasting the reductive and complexity paradigms (Cilliers 2008, Morin 2008, Ison et al. 2011). Here, we present a particular perspective that contrasts these different world views as context for bringing about change in peoples' consciousness, mindsets, and behavior when engaging with complex social–ecological systems.

The Reductive Frame of Reference

Reductive thinking has dominated Western thought patterns for at least three centuries and can be traced back to Aristotle's "logic" and then Descartes "Rules for the Direction of the Mind" (Montouri 2008). Indeed, reductive thinking has become such a societal habit (Kapferer 2004, Morin 2008) that it is seldom questioned by the general populace and even many scientists.

The centrality of reductive thinking in Descartes' rules is illustrated by the following texts from Rules 4, 5, and 6 (Descartes 1954):

Rule 4: reduce complicated ..... propositions step by step to simpler ones.

Rule 5: Once you have applied intuition to the simplest ones of all, try to ascend through the same steps to a knowledge of all the rest.

and

Rule 6: observe how all the rest are more, or less, or equally removed from the simplest.

In essence, Descartes proposed that the only sound thinking practice was to isolate phenomena from each other and their environment and apply a process of reduction, simplification, and clarification based on a disjunctive logic of "either/or," which he borrowed from Aristotle (Montouri 2008). Descartes (1954) went further to insist in Rule 6 that we must use this process to concentrate our mind's eye ..... long enough to acquire the habit of intuiting the truth distinctly and clearly. Indeed society has done just that, and the reductive thinking pattern, which rejects any form of integration, ambiguity, or paradox, became cemented in the Western way of life first by Newton and then by the industrial revolution.

Newton fathered the "scientific method" (also referred to as "reductionism") of using experiments to break systems down into their simplest components, or building blocks, in order to understand them. Newton also considered the world "reversible," which implies that the past and future have no real significance (Montouri 2008) and errors can be precisely rectified. The technology developed to drive the industrial revolution was built with this thinking to ensure repeated production of identical units in identical ways. The coup de grâce of reductionism came from the growth of organizational bureaucracies (Montouri 2008), which provided "managers" with the tools to isolate and categorize tasks and decisions before allocating them individually within a hierarchically structured workforce.

The reductionist mindset seeks to understand the world as a collection of separable and thus independent units and assumes linear cause-and-effect relationships between these units and that these relationships are reversible. A system and its parts are, therefore, assumed to have an ultimately knowable structure and behavior. The belief that a system, and ultimately reality, is identifiable and knowable has very important implications for decision making because it supports and legitimizes the notions that we can both "get it right" and, if something goes wrong, "reverse it." This in turn leads to the assumption that we can directly or indirectly control the decision process. Even more important in action research and problem solving is that, if in theory it is possible to get it right and/or fix it, then stakeholders will rightfully expect that we (who they may see as experts) do so.

The use of the reductionist paradigm in western society is, therefore, founded on at least three centuries of socially constructed habit (Berger and Luckman 1966, Kapferer 2004) that our social–bio–physical reality is ultimately knowable and that paths into the future are mapable (Cilliers 1999, Mitchell 2009). Under this perspective of reality, science and society built a deeply held confidence that good science makes scientists into disciplinary experts who can, given the right conditions, objectively provide decision makers with knowable and, by implication, certain facts and answers.

A Complexity Frame of Reference

Under the complexity paradigm, variability and uncertainty are valued givens, so complexity thinkers seek to understand systems in terms of the heterogeneity of their structure, relationships, and properties that emerge from interactions.

The many variable elements interact dynamically in a causal thicket (Wimsatt 1994) and interactions are propagated throughout the system in nonlinear ways. The behavior of a system is determined by the nature of interactions, not the character of the components, and so relationships are fundamental. Temporal (history) and spatial contexts codetermine interaction outcomes, so two similar-looking systems with different histories, or in different places, are not the same. There are many direct and indirect feedback loops, so the scale of the effect is not related to the scale of the cause, and behavior cannot be predicted from knowing the components. Complex systems are not ultimately knowable in space or time (Cilliers 2000), and thus scientific objectivity becomes largely a myth and not necessarily desirable, let alone sacrosanct.

Under a complexity perspective of reality, problems are wicked (Rittel and Webber 1973), and there are multiple legitimate ways of framing each question. You cannot fully understand a problem until you have found a solution, but each solution is a one-shot operation (Conklin 2006) because each one you try has unintended consequences that are likely to spawn new problems. In other words, wicked problems have no stopping rules (Ludwig 2001, Conklin 2006), and there cannot be an a priori or ex situ test of effectiveness of solutions. Each wicked problem is essentially unique and novel, and there can be no right or wrong framing of either the problem or solution.

Indeed, even the use of the term "problem solving" is inappropriate to wicked problems, and hence we use less prejudicial terms such as engaging with or addressing problems or challenges. We accept that wicked problems cannot actually be solved but rather the problem space can be loosened so that a wider range of options for action emerges.

THE CHALLENGE OF SHIFTING TO A COMPLEXITY FRAME OF REFERENCE

The most disquieting realization that people take away from the above descriptions of reductionist and complexity paradigms is that, without doubt, they present two very different pictures of reality. Given that social–ecological systems are complex, then a reductive–reductionist approach will indeed "disfigure" (Morin 2008:3) our perceptions of their reality. No one—not scientists, professionals, or lay people—is immune to the consequences of this realization. Nonetheless, a complexity view of the world is rare (Sterman 1994, Morin 2008), and the majority of professionals, disciplinary scientists, and lay stakeholders/decision makers whom one—and certainly the authors—engages when conducting action research have yet to encounter complexity thinking/science. They display all the distinctly reductionist habits of expecting to come to "know" the problem and objectively find the "right" solution by dividing the problem into discrete elements to be tackled by experts who "know" how to do it (Zellmer et al. 2006). Any range of solutions can be tried because, if they go wrong, they can be reversed with little consequence for the system. They will expect, consciously or unconsciously, that once the "real" solution is reached, the problem will go away and they will now have an "evidence-based" decision that can be applied again should "the" problem emerge again.

Fostering a change in people's frame of reference is much more than just adding to their knowledge base, it implies changing their mindset and behavior (Brock and Solerno 1998, Senge et al. 1999) in a process of "transformative learning" (Mezirow 2003). Much has been written about the process of learning, and there are many models of how individuals, groups, and institutions gain knowledge, learn, and change behavior. It is beyond our scope to review this literature, but we will briefly explore four common conceptualizations that are useful in building a framework of learning in a complex system. These are the (1) explicit/tacit knowledge framework (Polanyi 1983), (2) unlearning selective exposure (Rogers 1995, Miller and Morris 1999), (3) conscious/competence learning matrix (Howell 1982), and (4) model of learning loops (Argyris and Schön 1974).

Explicit/Tacit Knowledge Framework

A person's knowledge is defined by a mix of their experiences, values, contextual information, and intuition (Davenport and Prusak 1997, Roux et al. 2006), which is used to evaluate new experiences and information and prepare for action (Dawson 2000). Knowledge in this sense has two dimensions: explicit knowledge that comes in the form of written reports, publications, or other media that we experience on a regular basis, and tacit knowledge (Polanyi 1983) that is highly personal and deeply rooted in an individual's experience, ideals, values, and emotions. Tacit knowledge is very difficult to formalize and share with others, but if only explicit knowledge is recognized, we grossly underestimate the true effort required for knowledge transfer and thus learning. Exchanging context-laden tacit knowledge requires a shift from viewing knowledge as a thing to be transferred to viewing its acquisition as a process of negotiating meaning among partners. Negotiating meaning is slow and requires lasting partnerships that provide the time and opportunity to build mutual trust (Roux et al. 2006).

Unlearning Selective Exposure

Surprisingly, one of the biggest impediments to changing one's world view or paradigm is what you already know, because human learning patterns are strongly influenced by previously accumulated knowledge (Cohen and Levinthal 1990). Indeed, the more a person's worldview is shaped by learning within a defined field, the harder it becomes to associate with what emerges from other fields. Miller and Morris (1999) refer to this tendency as trained incapacity and emphasize the conundrum that, the more we know about something, the harder it is to unlearn, before it can be replaced by something else. Rogers (1995) refers to the same phenomenon as the path of selective exposure whereby an individual protects existing knowledge by disregarding conflicting or unrelated information.

Our challenge in action research is to enable people to become sufficiently competent in complexity thinking and conscious of the reality it projects, that they have the confidence to unlearn their long-imposed path of selective exposure and trained incapacity in the habit of reductionism.

Conscious/competence learning matrix

The "conscious competence learning matrix" (Howell 1982) has proved a durable model of the process and stages people go through in becoming aware of, and learning, new knowledge, skills, or behavior. The learner is considered to always begin at stage 1, "unconscious incompetence," and end at stage 4, "unconscious competence," having passed through stages 2, "conscious incompetence" and 3, "conscious competence."

- *Unconscious incompetence* applies when people do not recognize or understand that there is a deficit. They either do not know that some knowledge exists, or they deny its usefulness. They don't know that they don't know!
- *Conscious incompetence* is found in people who do recognize the deficit and the value of addressing it but do not understand or know how to do something about it. They know they don't know!
- In *Conscious competence*, the individual understands or knows how to do something, and heavy conscious involvement is required to use the skill or knowledge, or demonstrate it to others. They know they know!
- When a skill or knowledge set becomes second nature, individuals are said to exhibit *unconscious competence*. They don't know they know!

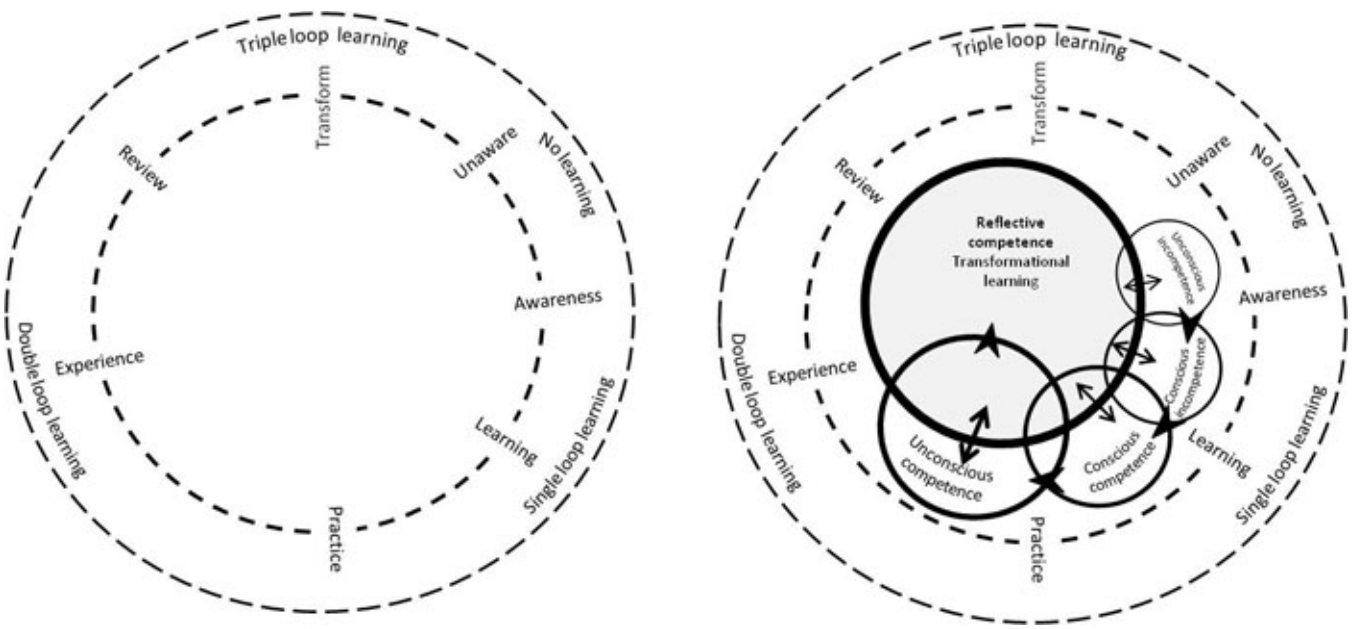
A number of authors have questioned the assumption that learning would end with unconscious competence, particularly in respect of how someone who is unconscious of their competence can pass their knowledge and skill on to others (Nonaka, 1994, Chapman 2012). There have been many suggestions on how to deal with this. Taylor ((2007) in Chapman 2012) proposed a fifth stage, termed reflective competence, to illustrate that people would continually revisit and challenge their conscious incompetence to discover holes in their knowledge that they need to fill. Indeed, a critical element in advancing through any learning process is that of reflection (Grimmett et al. 1990, Raelin 2001, Mezirow 2003).

Learning loops model

The last model we introduce describes three different levels of learning and knowing based on the depth of reflection needed to translate knowledge into action. The learning loops model was introduced by Argyris and Schön (1974), who proposed two loops, single and double. The model was later revised to include a third loop (Raelin 2001).

- *Single-loop learning*, also known as practical knowing, is mediated through deliberation among competing versions of effective practice leading to general rules of

Fig. 1. An integrated framework for the complex stages and processes of learning and adopting new knowledge, skills, or frame of reference. The first step for anyone is becoming aware of the need to learn. This learning must proceed through practice and review from single- to double- to triple-loop learning (left-hand diagram). Changing levels of consciousness and reflection then lead to deeper learning that can change one's frame of reference. The framework (right-hand diagram) presents a number of stages along the path to a mature understanding and reflection that continually challenges one's path of selective exposure. Unlearning happens during, or as a consequence of, repeated incursions into reflective mode and back again (Modified from Taylor (2007, in Chapman 2012)).



thumb that can be used repeatedly, without the need for recourse to the governing variables.

- *Double-loop learning*, propositional knowing, occurs when we challenge our assumptions (practical knowing) enough to question the transfer of learning and doing from one context to another.
- *Triple-loop learning*, dialectical knowing, is when we go to higher order context to challenge our premises and entire frame of reference before taking action.

Together, these four models provide a useful framework for describing learning processes in a complex system (Fig. 1). In the context of the reductionism/complexity contrast, single-loop learning would equate to someone who habitually used reductionism even when dealing with dynamic systems. As there is no useful halfway house between reductionist and complexity thinking, there should be no case for double-loop learning in this context. Morin (2008), however, asserts that pseudocomplexity thinking abounds in approaches and people who define themselves in opposition to the tenets of reductionism but do not consistently live complexity. Such people would also be described as having a trained incapacity, as a result of selective exposure to reductionism, so deep that although they are conscious of their incompetence, they are incapable of unlearning the old invalid thinking processes. Both learning and unlearning are made more difficult by the fact that much knowledge about the use of complexity thinking is currently in tacit form because living complexity is still very much in its infancy and yet to be made explicit.

Engaging the framework (Fig. 1, right) begins with unawareness. Most of the stakeholders we encounter are in stage 1 (unconscious incompetence). They are unaware of their trained incapacity in reductionism and that their path of selective exposure has left them ignorant of complexity thinking. Awareness can be stimulated (movement to stage 2, conscious incompetence) by contrasting the perceptions of reality that can be experienced under the two different paradigms and by relating a range of examples from our experiences. As people reflect on these new world views, they achieve awareness of the limitations of their current mindset and engage in single-loop learning by slowly accepting some different ways of thinking. Continued and stimulated (by, for example, action research facilitators) reflection on their awareness brings to light examples from their own experiences, providing some comfort against the self-doubt they feel. Slowly, with repeated exposure and facilitation, their

knowledge and confidence grows (hence the increasing size of the circles in Fig. 1) and competence begins to emerge. Repeated practice of what they have learned moves them into double-loop learning. Once again, reflection on things such as experiences of the differences in outcome that might arise from the use of the different paradigms dampens the doubt and raises the confidence that facilitates movement to the next stage.

In a real social–ecological system, different parts of each individual's tacit knowledge, and thus frame of reference, will be in different stages of this learning cycle. Something they grasp quickly will move through the cycles quicker than something they have difficulty comprehending. Something they have just become aware of will be less conducive to reflection than something they have gained some competency in. Consequently, different knowledge, attitudes, and skills of individuals will be in different stages of the learning cycle and will move through at different rates. Similarly, different individuals will be differentially ready to become conscious of and learn about a new frame of reference such as complexity.

At any given time, a facilitator or leader of an action research program is faced with participants who each have multiple frames of reference, each at a different stage of maturity, that they are differentially able to bring to the consciousness of the research team. Any assumption that stakeholders have similar frames of reference, or are similarly ready to learn and reflect on a wicked problem, is extremely dangerous. Especially when trying to foster a complexity frame of reference in the participants.

Consider how researchers begin interacting with participants when starting an action research program that entails embedding complexity thinking in an institution. One of the first actions might be to present participants with a handout that describes the need to change their frame of reference and explains how they should start thinking as the program gets underway. Researchers may be tempted to include a list of hints for complexity thinking and their no-go reductionist contrasts. The handout might be a good idea but it would of course only represent some explicit knowledge. Participants would need to gain firsthand experience of such thinking patterns if they were to effectively progress through the learning process. The facilitators can provide this by "walking-the-talk" and exposing their tacit knowledge of complexity thinking in the process. In the next section, we present, for the first time in explicit form, the outcome of the authors' attempt at surfacing their tacit complexity thinking framework. This tacit knowledge comes from years of experience in facilitating action research programs in social–ecological systems in the fields of biodiversity conservation, water resources, and catchment management, and helping businesses and government institutions rethink their planning and management approaches.

FRAMES AND HABITS OF MIND FOR COMPLEXITY THINKERS

We find that the most important competencies that enable effective use of this integrative learning framework are psychological. They are ways of thinking that allow one to unlearn reductionist habits while adopting and embedding those more conducive to working in complex systems. We have adapted the educational learning concept of "Habits of Mind" developed by Arthur Costa and colleagues (Costa 1991, Costa and Kallick 2008) to foster intelligent thinking in school children.

A habit of mind is a pattern of intellectual behavior that leads to productive actions. Habits of mind are seldom used in isolation but rather in clusters that collectively present a pattern of behaviors. When people are confused by dilemmas, or come face-to-face with uncertainties, their response is determined by the patterns of intellectual behavior upon which they can draw. This implies that people should maintain an awareness of, and make conscious choices about, which patterns of intellectual behavior (habits of mind) are most appropriate to use under which circumstances. A certain level of competency is then required to use, carry out, and sustain the behaviors effectively, and also to reflect upon, evaluate, and modify them for future use under different conditions.

Moving one's self, or a group of stakeholders, from one position of competency to another is unlikely to happen unless thinking and doing are bounded by particular intellectual patterns. We recognize three broad frames of mind, each of which encompasses a set of habits of mind that are critical to leading participative planning and decision making in complex social–ecological systems. These frames of mind are openness, situational awareness, and a healthy respect for, what we term, the restraint/action paradox.

Openness (see Text Box 1)

To embrace and effectively engage with complexity requires a certain psychological openness from individuals and institutions, especially when in transition from a predominantly reductionist paradigm. This openness can be described as a willingness to accept, engage with, and internalize the different perspectives, even paradigms, to be encountered when dealing with diverse participants in an interdisciplinary situation. An open frame of mind requires conscious acceptance that notions such as ambiguity, unpredictability, serendipity, and paradox will compete strongly, and legitimately, with knowledge, science, and fact. In essence, it means that while navigating challenges of a complex social–ecological system, one holds one's own strong opinions lightly (Pfeffer and Sutton 2006) and engages as both facilitator and learner.

Box 1:
Habits of mind that promote patterns of openness in behavior

- Hold your strong opinions lightly and encourage others to do the same.
- Be prepared to identify and accept the intervention of surprise, serendipity, and epiphany.
- Encounter every person with equal respect, listen for their specific needs, knowledge, and ways of knowing.
- Be open to both/and options.
- Do not reject ambiguity or paradox. They are to be expected and their acceptance as legitimate can often avoid dispute.
- Cultivate, honor, and affirm the legitimacy of multiple perspectives and outcomes. Be ready to chart your way through them to learn about multiple legitimate outcomes: there are many ways of skinning the cat.
- Accept everyone as colearners, not experts or competitors.
- Encourage cooperation and consensus: the best way to get what you need is to help others get what they need.

Box 2:
Habits of mind that promote patterns of situational awareness in behavior

- Discern when a change is sufficient to require renegotiation or review.
- Consider the importance of relationships and interactions between entities and not just the entities themselves.
- Become conscious of and accept change agents and processes.
- Be time and place specific: without it you cannot properly identify the appropriate context or define problems and solutions.
- Be aware of contingencies, scale, and history: they all play a role in mapping the present and the future.
- Surface the collective principles and values that will bound decision situations and help keep decision making consistent from one context to the next.
- Use these principles to guide decision making, rather than relying on facts and numbers, which will change with context.
- Reflect often: formally, informally, individually, and collectively.

Situational Awareness (see Text Box 2)
One of the critical differences between complexity-based and reduction-based thinking is the importance of context and scale in complex systems. Each issue or system attribute can appear quite different, and interactions have quite different outcomes, under different contexts and at different scales (Levin 1998, Dollar et al. 2007). Spatial and historical context are very important, but so too are the different participants' value systems and how they lead to different outcomes. We use the acronym V-STEEP (Values—Social, Technical, Economic, Environmental, and Political) (Rogers and Luton 2011) to guide us when scoping context. An awareness of the complex context in which an adaptive challenge exists, and of how it changes in time and space, is critical to effectively navigating through it. In essence, one must cultivate a state of anticipatory awareness and constant mindfulness of the V-STEEP environment when navigating complex systems.

A Healthy Respect for the Restraint/Action Paradox (see Text Box 3)
Leadership and decision making in a complex system constitute a balance between the risks associated with practicing restraint and taking action. On the one hand, if the context requires it, one needs to consciously practice restraint and create space that allows the emergence of ideas, trust, opportunity, and even epiphany to loosen the tangled problem knot. There is a strong need for a certain slowness (Cilliers 2006) in taking time to allow emergence to unfold. On the other hand, one needs the courage to take action in a mist of uncertainty because, in a complex system, the consequences of our actions are never entirely predictable, and no matter how good our knowledge, there is never an objective "right" decision. Being conscious of, and comfortable with, this paradox is critical to successfully fostering and practicing adaptive leadership in social–ecological systems.

Box 3:
Habits of mind that promote patterns of a healthy respect for the restraint/action paradox

Decisiveness/willingness to act under tension

- Encourage courage. Do not be afraid of intelligent mistakes.
- Avoid paralysis from the paranoia of omission, and/or fear of simplicity.
- Have the courage to seize the just-do-it moment.
- Accept that there is no one right place to start or end. Do so when it is sensible and useful.
- Have courage to take action from which you can learn. Even mistakes lead to learning.
- Cultivate an awareness of the natural inclination to avoid discomfort and have the courage to push beyond it.

Restraint under tension

- Discern when to trust the facilitation process and stand back quietly, giving the group dynamic space and allowing emergence.
- Avoid premature convergence—avoid being too quick to make judgments and choices. Keep options on the table long past their apparent usefulness. Many will find context later in the process.
- Avoid overconfidence about being ready to take action in a data-driven "predict and act" mode.
- Know when to rest. Open and participatory engagement exposes vulnerabilities, requires humility, and takes energy
- Getting ahead of the game leaves participants unsettled and opens opportunities for dissent. Provide participants ample time for healing and replenishment.

These three frames of mind are interdependent, with openness as the foundation or most critical one of the three as it can enable or constrain the other frames. To some extent, adequate situational awareness is not possible without openness to a diversity of perspectives. In a complex system, one simply cannot afford a one-sided perspective. Knowing when to act and when to practice restraint depends on one's awareness of changing dynamics in the system, but it also requires openness to the unexpected. The more specific habits of mind are more easily contextualized, remembered, and taught when grouped under these frames, but they are not confined to use under one frame. As one becomes more competent in their use, they are easily moved or modified from one context to the next. This list of habits is a living list that is continually honed as we learn more from explicitly applying complexity thinking to social–ecological problem situations.

HABITS OF MIND AS HEURISTICS TO GUIDE ACTION AND LEARNING

The scientific literature on social–ecological systems strongly advocates adaptive approaches to decision making, which come under many guises. For illustrative purposes, a typical adaptive decision process consists of four main steps: (1) framing the issue and its context; (2) deciding; (3) doing; and (4) reviewing. As can be expected, each of these steps presents different contexts and opportunities for the use by complexity thinkers of different combinations of habits of mind. Although the following text is far from comprehensive, it does illustrate how individual habits of mind might be used in context-specific ways while moving through these steps.

Framing the Issue and Its Context

Framing can be understood as a form of scoping in which we are explicit about developing a complexity perspective of both the issue at hand and its particular context. It is not a step-by-step approach as reductive thinking would suggest. A more complexity-friendly description might be that it is more akin to trying to unravel the knots in a hastily gathered bundle of string, or in fishing line that has stripped from a reel. One cannot understand the bundle (issue) without trying to unravel it (solve it) and vice versa. Tugging at one point can loosen some parts of the knot but tighten others, so the process needs a holistic and empathetic approach.

A high degree of openness must be cultivated as stakeholders explore the thicket of social, technical, economic, environmental, and political (STEEP) attributes of the issue (question, problem), its context, and potential solutions in a scaled, spatially and temporally explicit, and participative way, acknowledging the importance of values (V-STEEP) (Rogers and Luton 2011).

Critical habits of mind to encourage in this phase include holding one's strong opinions lightly and adopting a certain slowness, which together open time for shared reflection and learning. These grounding habits are essential in prodding participants to become conscious of how contingencies and feedbacks generate many different legitimate perspectives. Soon they also realize the limitations of rules, facts, and data in wicked problem decision making.

Deciding

Adopting a complexity-based frame of mind and practice opens a new world of decision possibilities usually unseen by the reductionist, who strives to eliminate all but the right perspective, answer, or solution. Participants can move quite suddenly from being in a position where there is one, or only

a small number of logical choices and actions, to a new situation where multiple choices become legitimate and viable in their own right. At the heart of the deciding step is proactive choice. It is a choice to make a decision in the apparent absence of the usual indicators of success for a particular path of action, rather than for a carefully constructed end point. It is the awareness that a choice has to be made, that it is likely to be imperfect, and that it will be provisional at best. Choosing a certain path of action is as much a psychological value-based standpoint as it is an entry into more learning. Choosing a path will take the practitioner to a new set of learnings from which to make new and more relevant choices in an iterative way.

Doing

Implementing a chosen action in a complex context is ultimately about getting started where it is sensible and/or useful to do so. It is in this space that action becomes a form of diagnosing and learning of the dynamics and interactions within the complexity. Practitioners need to be aware of the pressures to be acting continuously. It is difficult to justify not acting to decision and policy makers; however, there are times in complexity thinking when resting and taking no action is the best form of acting. This form of doing then acknowledges the inherent action within a complex system and becomes open to windows of opportunity that may arise. It contrasts with the reductionist tendency to undertake tasks in a predefined way and sequence, which invariably falls foul in the face of unexpected hitches.

Reviewing

Reviewing should be, but unfortunately is not, a natural occurrence after action, even in tightly controlled bureaucracies where emphasis is on the efficacy of the action, in and of itself. It is the most critical step in an adaptive process, as it initiates a new cycle of framing, deciding, doing, and reviewing. Without it, we become stuck in doing—often in an unproductive manner or direction. We need review so that we can reflect on and challenge our in/competencies and make our tacit habits of mind explicit. In a complexity context, formalizing the review process is difficult, given the number and variability of outcomes and the range of legitimate perspectives. It can be undertaken as a process of understanding and learning about the shifts in dynamics and direction within the complexity that arise as a result of choosing a certain path of action. Reflection in an open frame of mind is a critical aspect of reviewing in complexity.

CONCLUSION

In this paper, we describe why, in social–ecological systems dialog, it is crucial to be conscious of the realities of complexity and to adapt thinking and decision-making styles accordingly. Simply put, the key to understanding complexity is that it is antireductionist (Wagenaar 2007). It is also becoming abundantly clear that reductive thinking, which privileges systematic approaches over system complexity, provides a distortion of systems reality that can have, and indeed has had, considerable social cost (Montouri 2008, Morin 2008, Rogers 2008, Ison 2010). Lastly, it is widely held that systems and complexity thinking is a skill that far too few people have and even fewer can practice (live) (Nowotny et al. 2001, Funtowitz and Ravetz 1992, Wagenaar 2007, Morin 2008, Ison 2010). In Ison's (2010) words, most people rarely make it to complexity's first base because they are trapped in a dominant linear, causal mode of thinking typical of the reductive mindset.

This presents serious problems and even ethical dilemmas (Cilliers 2000) for action research projects where the stakeholders (citizens, professionals, and researchers of all persuasions and origins) and researchers plan and implement interventions (new policy, management actions, resource redistribution, etc.) with the aim of generating transformation in social–ecological systems. Many intellectual and case-study publications that espouse this view exhort readers to adopt a complexity frame of reference, but few explain what complexity thinking is and how can it be harnessed in practice.

In the introduction, we identified three main challenges for action research in this context.

Firstly, researchers and their stakeholder partners must become conscious of their current frames of reference and how they are located within reductionist or complexity paradigms. We have explained that they must guard against "pseudo complexity" thinking (Morin 2008), in which complexity principles are espoused, but communication and action practices are still influenced by a reductionist legacy that remains to be unlearned from their knowledge base.

Secondly, the process of assimilating and internalizing new knowledge, to the extent that it transforms world views, is itself complex. We have developed an integrated framework for how learning in complex systems can lead to transformation of a person's frame of reference. This framework is less linear than its predecessors and illustrates the multiple paths, processes, and rates of how learning takes place in and about complex systems. Any assumption that stakeholders have similar frames of reference, or are similarly ready to learn and reflect on a wicked problem, is highly flawed but often made, even if unconsciously. At any given time, the action researcher/facilitator is faced with stakeholder partners/participants who each have multiple frames of reference, each of which is at a different stage of maturity, that they are differentially able to bring to the consciousness of the research team. Attempts to foster a new frame of reference must acknowledge this diversity and avoid inappropriate step-by-step guidelines of learning processes.

Thirdly, intellectual acceptance of the characteristics of complex systems is only the foundation on which to start building a new set of thinking patterns and behaviors. The

challenge is to be explicit about the types of habits of mind that could be used as heuristic tools through which researchers and stakeholders can begin to better "live" complexity.

The concept of action researchers and their partners "living" complexity is an important one because the learning and understanding processes that lead to transformation are not complete without experience of, and feedback from, application. Future use of our frames and habits of mind in activities such as policy implementation, governance, and other participative decision processes will deepen understanding of both intellectual and lived complexity, which in turn should lead to improved models to better enhance the communicative space in complex systems.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5330

Acknowledgments:

Funding from the National Research Foundation of South Africa is gratefully acknowledged. Dirk Roux and Kevin Murray gave useful comment on an earlier draft.

LITERATURE CITED

Argyris, C., and D. A. Schön. 1974. *Theory in practice: increasing professional effectiveness.* Jossey-Bass, San Francisco, California, USA.

Berger, P. L., and P. L. Luckman. 1966. *The social construction of reality: a treatise in the sociology of knowledge.* Anchor Books, New York, New York, USA.

Brock, L. R., and M. A. Salerno. 1998. *The secret to getting through life's difficult changes.* Bridge Builder Media, Washington, D.C., USA and Durban, South Africa.

Chapman, A. 2012. *Conscious competence learning model: four stages of learning theory—unconscious incompetence to unconscious competence matrix—and other theories and models for learning and change.* Businessballs, Leicester, UK. [online] URL: http://www.businessballs.com/consciouscompetencelearningmodel.htm

Cilliers, F. P. 1999. Complexity and postmodernism. Understanding complex systems. Reply to David Spurret. *South African Journal Philosophy* 18:275–278.

Cilliers, F. P. 2000. What can we learn from a theory of complexity? *Emergence* 2:23–33 http://dx.doi.org/10.1207/S15327000EM0201_03

Cilliers, F. P. 2006. On the importance of a certain slowness. *Emergence: Complexity and Understanding* 8:106–113.

Cilliers, P. 2008. Complexity theory as a general framework for sustainability science. Pages 9–26, *in* M. Burns and A. Weaver, editors. *Exploring sustainability science—a Southern African perspective.* African Sun Media, Stellenbosch, South Africa.

Cohen, W. M., and D. Levinthal. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* 35:128–152. http://dx.doi.org/10.2307/2393553

Conklin, J. 2006. Wicked problems and social complexity. Chapter 1 *in* J. Conklin. *Dialogue mapping: Building shared understanding of wicked problems.* Wiley, New York, New York, USA.

Costa, L. editor. 1991 *Developing minds: programs for teaching thinking* Revised edition, Volume 2 (pages 27–32). ASCD (formerly Association for Supervision and Curriculum Development), Alexandria, Virginia, USA.

Costa, L., and B. Kallick. editors. 2008. *Learning and leading with habits of mind.* Product # 108008, Association for supervision and curriculum development, Alexandria, Virginia, USA.

Davenport, T. H., and L. Prusak. 1997. *Working knowledge: how organizations manage what they know.* Harvard Business School Press, Boston, Massachusetts, USA. http://dx.doi.org/10.1145/347634.348775

Dawson, R. 2000. *Developing knowledge-based client relationships—the future of professional services.* Butterworth Heinemann, Boston, Massachusetts, USA.

Descartes, R. 1954. *Rules for the direction of the mind. In* E. Anscombe and P. Geach. *Descartes: philosophical writings.* Bobbs-Merrill Educational Publishing, Indianapolis, Indiana, USA. [online] URL: http://en.wikisource.org/wiki/Rules_for_the_direction_of_the_mind

Dollar, E. S. J., C. S. James, K. H. Rogers, and M. C. Thoms. 2007. A framework for interdisciplinary understanding of rivers as ecosystems. *Geomorphology* 89:147–162. http://dx.doi.org/10.1016/j.geomorph.2006.07.022

Funtowicz, S. O., and J. R. Ravetz. 1992. Three types of risk assessment and the emergence of post normal science. Pages 251–273 *in* S. Krimsky and D. Golding, editors. *Social theories of risk.* Greenwood, Westport, Connecticut, USA.

Grimmett, P. P., G. L. Erickson, A. M. MacKinnon, and T. J. Riecken. 1990. Reflective practice in teacher education. Pages 20–38 *in* R. T. Clift, W. R. Houston, and M. C. Pugach, editors. *Encouraging reflective practice in education: an analysis of issues and programs.* Teachers College Press, New York, New York, USA.

Habtemichael, F., and F. Cloete. 2010. Complexity thinking in the fight against corruption: some perspectives from South

Africa. *Politikon* 37:85–105. http://dx.doi.org/10.1080/0258-9346.2010.492151

Hart, E., and M. Bond. 1995. *Action research for health and social care: a guide to practice.* Open University Press, Buckingham, UK.

Holling, C. S., and C. R. Allen. 2001. Adaptive inference for distinguishing credible from incredible patterns in nature. *Ecosystems* 5:319–328. http://dx.doi.org/10.1007/s10021-001-0076-2

Howell, W. S. 1982. *The empathic communicator.* Wadsworth Publishing Company, University of Minnesota, St. Paul, Minnesota, USA.

Hult, M., and S. Lennung. 2007. Towards a definition of action research: a note and bibliography. *Journal of Management Studies* 17:241–250. http://dx.doi.org/10.1111/j.1467-6486.1980.tb00087.x

Ison, R., K. Collins, J. Colvin, J. Jiggins, P. P. Roggero, G. Seddaiu, P. Steyaert, P. Toderi, and C. Zanolla. 2011. Sustainable catchment managing in a climate changing world: new integrative modalities for connecting policy makers, scientists and other stakeholders. *Water Resources Management* 23:3977–3992. http://dx.doi.org/10.1007/s11269-011-9880-4

Jayasinghe, S. 2011. Conceptualising population health: from mechanistic thinking to complexity science. *Emerging Themes in Epidemiology* 8:2 [online] URL: http://www.ete-online.com/content/8/1/2 http://dx.doi.org/10.1186/1742-7622-8-2

Kapferer, B. 2004. The social construction of reductionist thought and practice. *Social Analysis* 48:151–161.

Kay J. J., H. A. Reiger, M. Boyle, and G. Francis. 1999. An ecosystem approach to sustainability: addressing the challenge of complexity. *Futures* 31:721–742. http://dx.doi.org/10.1016/S0016-3287(99)00029-4

Levin, S. A. 1998. Ecosystems and the biosphere as complex adaptive systems. *Ecosystems* 1:431–436. http://dx.doi.org/10.1007/s100219900037

Ludwig, D. 2001. The era of management is over. *Ecosystems* 4:758–764. http://dx.doi.org/10.1007/s10021-001-0044-x

Mazzocchi, F. 2008. Complexity in biology: exceeding the limits of reductionism and determinism using complexity theory. *European Molecular Biology Organization Reports* 9:10–14. http://dx.doi.org/10.1038/sj.embor.7401147

Mezirow, J. 2003. Transformative learning as discourse. *Journal of Transformative Education* 1:58–63. http://dx.doi.org/10.1177/1541344603252172

Miller, W. L., and L. Morris. 1999. *4th generation R&D—managing knowledge, technology, and innovation.* Wiley, New York, New York, USA.

Mitchell, S. D. 2009. *Unsimple truths: science, complexity and policy.* University of Chicago Press, Chicago, Illinois, USA. http://dx.doi.org/10.7208/chicago/9780226532653.001.0001

Montouri, A. 2008. Foreword: Edgar Morin's path of complexity. Pages vii–xiv *in* E. Morin. *On complexity.* Hampton Press, New Jersey, USA.

Morin, E. 2008. *On complexity.* Hampton Press, New Jersey, USA.

Nonaka, I. 1994. A dynamic theory of organizational knowledge creation. *Organization Science* 5:14–37. http://dx.doi.org/10.1287/orsc.5.1.14

Nowotny, H., P. Scott, and M. Gibbons. 2001. *Re-thinking science: knowledge and the public in an age of uncertainty.* Wiley-Blackwell, Oxford, UK.

Ostrom, E. 1990. *Governing the commons: the evolution of institutions for collective action.* Cambridge University Press, Cambridge, UK. http://dx.doi.org/10.1017/CBO9780511807763

Ostrom, E. 2002. Managing resources in the global commons. *Journal of Business Administration and Policy Analysis* 30:401–413.

Pfeffer, J., and R. I. Sutton. 2006. Evidenced-based management. *Harvard Business Review* 84:62–74.

Polanyi, M. 1983. *Tacit dimension.* Peter Smith Publisher Inc., Gloucester, Massachusetts, USA.

Raelin, J. A. 2001. Public reflection as the basis for learning. *Management Learning* 32:11–30. http://dx.doi.org/10.1177/1350507601321002

Reason, P., and A. Bradbury. 2007. *Handbook of action research.* Second edition. Sage, London, UK.

Rittel, H., and M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4:155–169 http://dx.doi.org/10.1007/BF01405730

Rogers, E. M. 1995. *Diffusion of innovations.* The Free Press, New York, New York, UK.

Rogers, K. H. 2008. Limnology and the post-normal imperative: an African Perspective. *Verhandlungen des Internationalen Verein Limnologie* 30:171–185,

Rogers, K. H., and C. M. Breen. 2003. The ecology–policy interface. *Frontiers in Ecology and Environment* 1:49–50. http://dx.doi.org/10.1890/1540-9295(2003)001[0050:TEPI]2.0.CO;2

Rogers, K. H., and R. Luton. 2011. *Strategic adaptive management as a framework for implementing integrated water resources management in South Africa.* Report No. KV 245/10. Water Research Commission, Pretoria, South Africa.

Roux, D. J., K. H. Rogers, H. C. Biggs, P. J. Ashton, and A. Sergeant. 2006. Bridging the science–management divide: moving from unidirectional knowledge transfer to knowledge interfacing and sharing. *Ecology and Society* 11(1): 4. [online] URL: http://www.ecologyandsociety.org/vol1/iss1/art4/

Scharmer, C. O. 2010. *The blind spot of institutional leadership: how to create deep innovation through moving from egosystem to ecosystem awareness.* Paper prepared for World Economic Forum, Annual Meeting of the New Champions 2010, Tianjin, People's Republic of China, September 2010. [online] URL: http://www.ottoscharmer.com/publications/articles.php

Senge, P., A. Kleiner, C. Roberts, R. Ross, G. Roth, and B. Smith. 1999. *The dance of change.* Nichols Brealey Publishing, London, UK. http://dx.doi.org/10.1002/pfi.4140380511

Simons, H. 2009. *Case study research in practice.* Sage, London, UK.

Snowden, D. J., and M. E. Boone. 2007. The leader's framework for decision making. *Harvard Business Review* November: 1–8. http://dx.doi.org/10.1037/e706682007-002

Stake, R. E., N. K. Denzin, and Y. S. Lincoln, editors. 2005. *The Sage handbook of qualitative research.* Sage Publications Ltd., Thousand Oaks, California, USA.

Sterman, J. 1994. Learning in and about complex systems. *System Dynamics Review* 10:291–321. http://dx.doi.org/10.1002/sdr.4260100214

Ulanowicz, R. E. A. 2009. *Third window: natural life beyond Newton and Darwin.* Templeton Foundation Press, West Conshohocken, Pennsylvania, USA.

Urry, J. 2005. The complexity turn. *Theory, Culture, Society* 22:1–14. http://dx.doi.org/10.1177/0263276405057188

Wagenaar, H. 2007. *Governance, complexity, and democratic participation: how citizens and public officials harness the complexities of neighborhood decline.* The American Review of Public Administration 37:17–50. http://dx.doi.org/10.1177/0275074006296208

Ward, D. 2005. T*he simplicity cycle.* Rouge press, Baton Rouge, Louisiana. [online] URL: http://www.lulu.com/product/download/the-simplicity-cycle/639 6210620#reviewSection

Wheatley, M. J. 2006. *Leadership and the new science: discovering order in a chaotic world.* BK Publishers, San Francisco, California, USA.

Wimsatt, W. C. 1994. The ontology of complex systems: levels of organization, perspectives, and causal thickets. *Canadian Journal of Philosophy* 20: 207–274.

Yin, R. K. 2009. *Case study research: design and methods.* Sage, Thousand Oaks, California, USA.

Zellmer A. J., T. F. H. Allen, and K. Kesseboehmer. 2006. The nature of ecological complexity: a protocol for building the narrative. *Ecological Complexity* 3:171–182. http://dx.doi.org/10.1016/j.ecocom.2006.06.002

Zimmerman, B. 1999. Complexity science: a route through hard times and uncertainty. *Health Forum Journal* 42:42–47.