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COMPLEX REGENERATIVE CREATIVITY

> If the transition is to be made—if the world is to make the change from the degenerative to the *regenerative* and thus sustainable mode—then priorities must change….With more interactions involved, more options available, and far more flexible technologies to deal with, regenerative design provides virtually unlimited opportunities for *invention* and for *devising varied ways of combining elements*. In such situations, analysis and deterministic methods usually provide knowledge of parts and mechanisms, but they rarely yield adequate answers. *Creativity enters the process in the key role of assembling diverse parts, often in unexpected ways.* Regenerative design involves both art and science not separately but merging together.
>
> – J. T. Lyle (1994, pp. 37–38, 45) *(emphasis added)*

Positioned at the vital intersection of chaos, systems thinking, fractals, creativity, and regeneration, this research theorises complex, regenerative creativity. Tracking the thinking of twenty creativity and chaos scholars, it traces parallels between the dynamics of the creative process and the conditions for chaotic emergence. Creative emergence and earth regeneration are both autopoietic. Connection with the regenerating patterns of living planetary systems can serve as a strange attractor for complex creativity. Process-patterns from nature and bioculture catalyse regenerative creativity and result in ethical and educative engagement and innovation, the enhancement of life-giving diversity, and the reduction of dogmatism. In particular, the transdisciplinary quality of ecofractal-activated regenerative creativity is consonant with the terrain of sustainability challenges. During this daunting epoch of the Anthropocene, complex regenerative creativity offers to crystallise the deep paradigm shifts required for planetary and local flourishing.

Spider Woman, a Navajo world-maker, spun the web of creation across the canyon-top lands. The drops of falling rain landing on the web made rainbows. These rainbows on the web drops sparked the imagination of five-fingered people (personal communication, John and Lupita McClanahan, Diné, September 9, 2011). Connection, creation, and creativity weave together. This research theorises a regenerative, complex creativity, positioned at the vital intersection of systems thinking, creativity, nature, and bioculture. The chapter traces parallels between chaotic and complex systems emergence and creative processes, particularly when catalysed by engagements with nature and bioculture. This inquiry articulates how

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complex creativity catalysed by process-patterns from nature and bioculture results in ethical and regenerative engagement and innovation.

THE SIGNIFICANCE OF REGENERATIVE COMPLEX CREATIVITY

We are offered increasing opportunities to deepen in our understanding and change our practices and systems to ones that sustain life. It becomes increasingly clear that the current, dominant systems of care and provisioning are harm-causing, insufficient, and unsustainable. Power consolidation, resource extraction, industry, and overconsumption have produced inequity, pollution, structural violence, species extinction, and planet-scale systems disturbance. Scholars currently describe the level of human impact as massive and planetary, hastening the era of the Anthropocene (Crutzen, 2006). Turbulence, extinction, and climate change from harming feedback loops point to the increasing attacks on the integrity of the fabric of planetary life. Superficial green-washing of industrial production threatens to distract us from effective, system-level innovations (Goleman, 2009) and the cultivation of ecological intelligence (Bowers, 2012).

Sustainability as a field engages in the triple considerations of equity, economics, and ecology to establish integrated approaches to these planetary challenges. It embodies "the urgent need for change from unsustainable practices towards advancing quality of life, equity, solidarity, and environmental sustainability" (UN Economic Commission for Europe, 2011, p. 7). Sustainability education (and education for sustainable development) explores how education can generate more sustainable and just economic and ecological systems, provoking "seismic" cultural shifts in paradigm, supporting "the necessity and possibility of a deep change in shared worldview if we are to manifest the transition towards a more liveable and sustainable world whilst workable options remain" (S. Sterling, 2009, p. 63).

Internationally recognised competences for educators in sustainability education offer holistic approaches that envision change to achieve transformation (UN Economic Commission for Europe, 2011). These competences include: (a) understanding systems thinking and the interdependent nature of relationships with generations, class, and nature while (b) emphasising problem setting, visioning, and creative thinking. The articulation of key sustainability literacies confirms the importance of (a) systems thinking and interdependence and (b) experiencing nature as model and teacher, including the ethnosciences (Nolet, 2009). This framework is consonant with the insights of many living wisdom traditions that connect creativity with ecological intelligence, biophilic affiliation, and traditional cultural knowledge, empowering a revitalisation of the local cultural commons (e.g., Bowers, 2012). Thus, during this daunting epoch of the Anthropocene, regenerative complex creativity offers to crystallise the deep paradigm shifts required for planetary and local flourishing.

Meanwhile, complexity, chaos, and creativity inspired by natural patterns are sourcing system-level innovation in an increasing number of arenas, including biomimetic invention (Bar-Cohen, 2006, 2012; Benyus, 2002), resilient social-

ecological governance (e.g. Berkes, Colding, and Folke, 2003; Waltner-Towes, Kay, and Lister, 2008), ecological design (e.g., Van Der Ryn & Cowan, 1996, 2007), regenerative design (e.g., Lyle, 1994), ecological integrity and collaborative transformation (Manuel-Navarrete, Kay, & Dolderman, 2004), living buildings, biophilic design, and architectures of renewal (e.g. Cumberlidge & Musgrave, 2007; Kellert, 2005; Murphy, 2011), and living systems education (e.g., Ambrose, 2009; Bache, 2008; Cohen, Manion, & Morrison, 2011; Davis & Sumara, 2006; Doll, Fleener, Trueit, & St. Julien, 2005; Mason, 2008; Widhalm, 2011). Other cultural forces also affirm the need for attending to complex creativity: technological amplification requires radically adaptive modes of creativity (Thomas & Brown, 2011) and increasing organisational and problem complexity requires greater creative capacities (Maubossin, 2011). Richards (2001b) emphasised, "Clearly, this is an important time for creativity" (p. 249).

To respond to this timely opportunity, I articulate a theoretical framework for how creativity, complexity, chaos, and regeneration are connected concerns. Creativity has chaotic properties and exhibits qualities of complex adaptive systems. The complex quality of autopoiesis, the ability to perpetuate self-arising/self-organising systems, can guide us to develop self-organising (autopoietic) creativity in education and design. Sustaining creativity has regenerative and ethical effects across domains. Patterns from nature and patterns from human-nature collaborations (bioculture) cross scales, in fractal and chaotic ways, and spark creativity in small groups to infuse design practices with regenerative results. Regenerative creativity sparked by ecological and biocultural fractals liberates genius and encourages and harvests divergence, diversity, and ethics (see Figure 1).

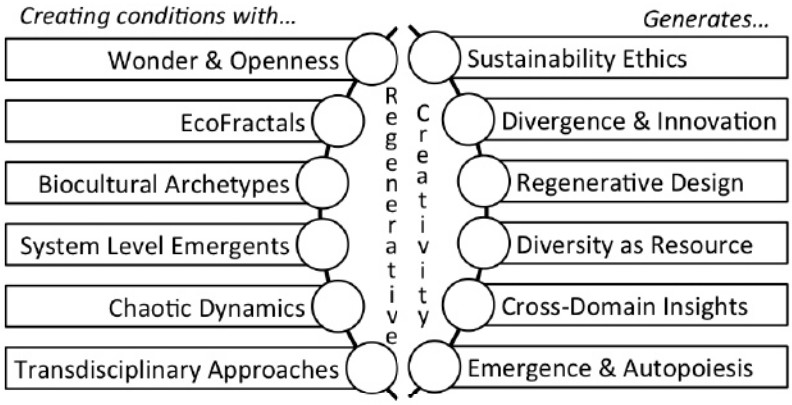

Figure 1. Conditions and qualities of regenerative creativity.

CREATIVITY, COMPLEXITY, CHAOS, AND REGENERATION

Creativity and chaos and complexity theory have long been linked. Educators, linguists, and researchers in multiple disciplines have identified this link (Fauconnier

& Turner, 2002; Taylor, 2011). Complexity-inspired research has sometimes been framed as *emergent participative exploration* (Christensen, 2005), *complex responsive processes perspective* (Stacey & Griffin, 2005), and *conceptual blending* (Fauconnier & Turner, 2002).

Complexity and regeneration are also connected. Autopoiesis, literally self-making (Capra, 1996, p. 97), is a concept from complexity science that marks the emergence of self-organisation for a system, particularly a living system. Capra's survey across the development of complexity science formulations identified several specific factors involved in complexity including: (a) the emergence of novel structures and behaviour modes that represent *new patterns of order* (b) within open systems operating in far from equilibrium states; with (c) a constant flow of energy and matter through them; (d) with system components connected in nonlinear ways; (e) resulting in amplifying feedback loops playing a central role; and (f) can best be described mathematically by nonlinear equations. He noted Eigen's hypercycles self-replication and Maturana's insight that these generate a network or web pattern of networks embedded in networks with a focus on the relationships and processes between components in which "the entire network continually 'makes itself'… produced by its components and in turn producing those components" (p. 98).

Capra (1996) described how the Gaia theory highlights this self-regenerating process via "a complex network of feedback loops that…bring about the self-regulation of the planetary system" such that, without teleology, life emerges and self-regulates (p. 104, 107). He noted that the emergent property of planetary temperature regulation arises consequent to the feedback loops between organisms and environment, not via any purposeful action. Margulis confirmed this planetary self-organisation phenomenon: life making, forming, and changing the environment within which it adapts (2004). As living systems are continuously regenerating and evolving, autopoietic complexity and regenerativity are related if not multivalently co-implicated across scale.

One could see creativity as a type of complex, regenerative process; in fact A. Sterling (2003) outlined exactly this parallel (see Figure 2) and noted that chaos theory and complex, dynamic nonlinear systems can unify the mechanistic and organismic views of creativity. In chaos theory, the farther a system from equilibrium, the more sensitive it is to slight changes in initial conditions, which is called sensitive dependence on initial conditions (SDIC).

A. Sterling found the question of setting initial conditions less interesting than understanding internal and external constraints on chaotic dynamics in creativity. In particular, she drew parallels with the traits characteristic of creative individuals—including those evidenced in the creativity research literature such as preferring nothing pre-structured, seeking out ambiguous situations, big-picture conceptualisation, flexibility, unconventionality, openness to experience, spontaneity, and overexcitability—and the chaotic dynamics of movement away from equilibrium.

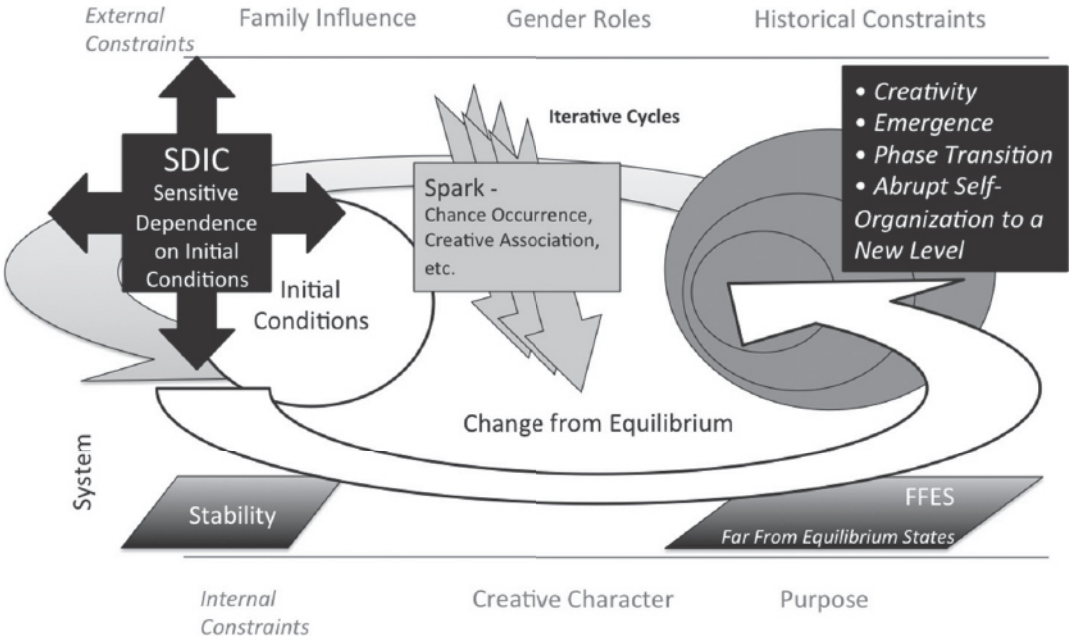

Figure 2. Human creativity and chaotic dynamics: Visualising A. Sterling's (2003) model.

The chaotic dynamics of creativity extend to amplification and feedback. A. Sterling (2003) insightfully suggested that "imaginational over-excitability…. may be an internal constraint that persistently pushes or entices individuals into far-from-equilibrium states" (pp. 163-164). Ambrose (2009) characterised this offbeat quality of high creatives as "a fruitful asynchrony of… those who don't quite fit in…[who] establish an uncomfortable but productive dynamic tension" (p. 71). A. Sterling found the purposefulness that leads to creative productivity described in the literature as possibly serving as "an 'initial condition' that encourages the human system towards a far-from-equilibrium state, thus priming it for a creative leap" (p. 165). She explored Gruber's concept that deviation-amplifying systems are necessary for creative work and that they support exploring and elaborating fledgling discrepancies or innovations. Deviation amplification represents an echo of Capra's inclusion of amplifying feedback loops as one of six characteristics of complexity. Researchers (Richards, 2001b; A. Sterling, 2003) have noted the important parallels between Csikzentmihalyi's work on flow and chaotic dynamics, including how challenging goals and burning questions can drive and amplify creative processes and how total concentration and joy are generative.

Chance and serendipity also play a role in creativity, much as seemingly random instigating perturbations in complex systems can cause generative self-organisation, also known as autopoiesis. There is a difference between sparking and sustaining creativity and complex systems. Regenerative systems are self-sustaining, just as autopoietic (generative) complex systems are self-sustaining as described by A. Sterling (2003):

> A system driven far-from-equilibrium by a variety of constraints is invaded by fluctuations caused by some factor that becomes amplified by the nonlinear dynamics, and the whole system spontaneously and abruptly reorganizes to a new level of organization…. [N]onlinear dynamics also can give rise to sustained processes. The new level at which a system arrives through self-organization may represent a new equilibrium. (p. 173)

In this way, regenerative creativity represents a systems-level, sustained gyre of innovation.

Other creativity and innovation scholars confirm the connection between generativity, creativity, complexity, and sustaining gyres of innovation. The conditions that spark regenerative creativity are *cultures* of innovation. Barron (1995) emphasised a complexity and systems approach to the ecology of creativity, which he considers emergent. Goldstein, Hazy, and Lichtenstein (2010) named these "ecologies of innovation," a "system-wide set of processes and interactions" that are characterized by systems of difference, adaptability, interaction resonance (feedback amplification), and using cooperative strategies and symbiosis (pp. 27-33). Wood (2013) advocated meta-design for creatives to realise *synergies of synergies* in ecomimetic sustainability design systems. Csikszentmihalyi's (1999) multiscale systems perspective of creativity noticed that support and understanding of the cultural domain and contexting field are required to nurture and proliferate individual creativity and give it meaning and persistence. Sawyer's (2010) research with improvisational groups generates insights into another complexity-informed theory regarding creativity beyond the individual, theorised as collaborative emergence. Collaborative emergence focuses on improvisation and action in group creative productivity, noticing the parallels between complex emergence and collaborative creativity. Another creativity researcher noticing correspondence between emergence and creativity cultures, Runco (2007) described nonlinear cascades of inventions that lead to subsequent inventions as creative emergence via trigger effects (from Burke) and *emergenesis*. The trigger effects Runco mentioned find a clear parallel with chaos's perturbations in contexts of sensitive dependence on initial conditions. These level-hopping, chaotic emergence cultures of creativity, including ecologies of innovation, domain and field feedback, collaborative emergence, and emergenesis, all indicate polyscale interactions for creativity and begin to describe the rich, emergent *edge of chaos* at which creativity can be continuously self-emerging, replenishing, and regenerative.

The intersection of chaos dynamics and creativity also drives Richards' explorations of fractal creativity. Richards (2001b) has explored the connections between chaos theory and creativity in depth via the Guilford Intellect Model for divergence and convergence. Richards' work focuses on the strange attractors of creativity that can either entrap or liberate and on exploration of individual as well as group-level effects. Richards applies the concept of strange attractors that in chaos indicate "an infinitely complex pattern in phase space that never exactly

repeats" as existing in cognition and creativity as "a mind screen of complex and interconnected pattern recognition devices" (p. 251). Richards finds that these meta-patterns can liberate with their infinite possibilities or overly constrict, as suggested by Schuldberg if they become bound to a limited-cycle or point attractors, what Goertzel (1995) identified as the chaotic strange attractors of belief systems.

These unfavorable but self-reinforcing habits of thought parallel system traps in, for example, the complex adaptive systems of ecosystems. System resilience (chaotic momentum) actually reinforces undesirable regimes (Gunderson, Allen, & Holling, 2010). Dogmatism is an example of this creativity-killing type of limited strange attractor of thought. Dogmatic insularity can "severly suppress, warp, or even destroy the development of creative intelligence" (Ambrose, 2012, p. 64). The regenerative design and ethics section at the end of this chapter further explores the possible relationships between ethical characteristics of regenerative complex creativity, which is the flip outcome from degenerative cycling of dogmatic point-attractors of thought.

Richards further noticed the fractal nature of memory paralleling Guilford's creative products treatment. Richards does note the parallel between novel creative insight, what A. Sterling refers to as hyperexcitability and the hypersensitivity of chaotic and complex systems. Richards (2001b) compellingly emphasised the process-nature of the chaotic patterns of divergent thinking. Capra (1996) articulated that the flow-through rather than the abstracted shape of the attractors and patterns is the important focus. Richards (2001b) calls these traits rather than states (2001b); Schuldberg described them as paths not outcomes (2007). Chaos mathematician Fleener focused on function, interactive pattern, and self-emergent structures rather than mechanistic relations (2002). This can be a difficult perspective for our shape-bound, morphological, scientifically trained cognition. Richards (2001b) applauded Guilford's systems and transformations within his taxonomy of products as emphasising dynamic evolution and movement:

> It is best, perhaps, to imagine these creative outcomes shimmering and transforming continuously in phase space—indeed, with each new thought or look we take….[A]ttractors lyleare dynamic…figures…constantly shimmering and twinkling in their areas of high activity and chaotic collapse, perhaps like stars seen through the atmosphere. Here is the constant ongoing arrival of creative insights, big and little, as the entirety accommodates to the arrival of each new part and reconfigures itself accordingly. Here are the bifurcating births of new possibilities that diverge from the context that spawned them and may take the configuration in new directions. (p. 254)

Inspired by this sparkling and dynamic complex creativity, Richards advocated for "living on the edge of chaos" in our creative lives as a way to position ourselves near dynamic, self-perpetuating patterns of sometimes disruptive, possibly eruptive change (p. 258). She further proposed creating learning cultures that "turn the heat up" on supporting positive divergence, an openness to nurturing eccentricity so

we do not miss the opportunity to collectively catalyse a shift (p. 259). Ambrose (2009) affirmed that individuals and cultures evolve and strengthen at this complex evolutionary edge of chaos. He suggested that chaotic order can provide the context for developing into higher levels of organisation, cultivating optimised balances of self-actualisation and cultural evolution while avoiding entrapment of fixity and culture-locking or excessive anarchic turbulence.

In sum, creativity exhibits nonlinear dynamics and chaotic, self-organising emergence. Table 1 synthesises both A. Sterling and Richards with twenty theorists to describe the "Parallels of Creativity and Chaotic Emergence." Open systems parallel wonder and an attitude of openness. Both external and internal constraints create the cauldron of context for the chaotic emergence of creativity. Habits of living on the edge of chaos generate far from equilibrium states. Imaginational overexcitability, spontaneity, serendipity, and novel assemblage correspond to sensitive dependence on initial conditions and can generate bifurcation points. Ongoing creative flow parallels flow-through for chaotic emergence. Habits of concentration, joy, and synergy offer amplifying feedback loops. Collaboration, novel associations, and transdisciplinary approaches create networks of networks and further reinforcing contexts. Culture gyres of innovation are sustained by regenerating autopoiesis. Patterns from nature and bioculture catalyse big picture emergence leading to gestaltic intuition.

Table 1. A Synthesis of Parallels – Creativity Phenomenon and Characteristics of Chaotic Emergence

Creativity Phenomenon (1,2,4, 5-22)	*Characteristics of Chaotic Emergence (1,2,3,9,10,17)*
Wonder, openness (1, 2); nurturing eccentricity (2); "diversity-positive"; positive divergence (4, 9); openness to experience (1, 2, 4, 10, 11, 12, 13, 14, 17)	Open Systems (1, 2, 3)
Imaginational overexcitability (1); spontaneity, serendipity (1, 2)	Sensitive dependence on initial conditions (SDIC) (1, 2, 3, 10, 17)
Age, culture, context – family influence, gender roles, historical context (1); domain and field contexts (11)	External constraints (1)
Creative character, purpose (1); e.g., prefer nothing pre-structured (2)	Internal constraints (1)
Living "on the edge of chaos" (2, 4, 10); hypersensitivity (1, 2); "fruitful asynchrony… of those who don't quite fit in" (4); openness to/seeking ambiguity (1, 2); live by improvisation and bricolage (10)	Far from equilibrium states (1, 2, 17)
Creative sparks, chance occurrence (1, 2, 10)	Bifurcation points (1, 2, 3, 9, 17)

(Continued)

Table 1. Continued

Creativity Phenomenon (1,2,4, 5-22)	*Characteristics of Chaotic Emergence (1,2,3,9,10,17)*
Patterns from nature (5, 6, 8, 9, among others); ecofractals (9); biocultural archetypes (9)	Bifurcation instigators; strange attractors; patterns; emergents (9)
Ongoing, creative flow (11, 1, 2); traits not states (2); paths not outcomes (10);	Emphasis on flow-through rather than shape or static structure/morphology (2, 3, 17)
Idea synergy, brainstorming, cooperation (1, 2); explore and elaborate fledgling discrepancies and innovations (2)	Amplifying feedback loops (1, 2, 3, 9); (e.g., hypercycles) (3)
Total concentration and joy (1); challenging goals and burning questions (1)	Amplifying feedback loops (1, 2, 3, 9)
Pattern recognition; big picture conceptualisation (4); holism, gestaltic intuition (6)	Emergence (3, 9, 17); strange attractors (1, 2, 9, 10); patterns, fractal patterns, patterns of order (1-9); system meshing (7); collective beings (20)
Collaboration, novel connections (1, 2); novel assemblage (7); creative association (1, 2); double scope blended networks (7); transdisciplinary approaches (1, 2, 3, 4, 6, 7, 8, 9, 13, 15, 16, 19, 20, 21)	Create networks, webs (3, 9); networks of networks (3, 9); emergent new multisystems (20); metaparadigm (21)
Systems-level sustaining gyre of innovation (this chapter, 9); creativity systems at the intersection of field, domain, and creator (11); creative collaborative emergence (12); cultural ecologies of innovation (13); a systems approach to an ecology of creativity (19); emergenesis catalysed by trigger effects (14); synergies of synergies (18); ecological intelligence (16); riding the storm toward connective cultural consciousness (15)	Autopoiesis (3, 17, 20); makes more of itself, sustains itself (2, 3); regenerates (8, 9); self-organisation (1-4, 7-10, 17); "reflecting their always original and self-renewing natures" (10)

Note. A synthesis of direct phrases and concepts from (1) A. Sterling (2003); (2) Richards (2001b); (3) Capra (1996, 2002); and (4) Ambrose (2009); with (5) Cobb (1977); (6) Mathews (2008); (7) Fauconnier & Turner (2002); (8) Lyle (1994); (9) Hauk (2007, 2011, 2013a, 2013b, 2013c); and including (10) Schuldberg, 2007; (11) Csikszentmihalyi (1990, 1999); (12) Sawyer (2010); (13) Goldstein, Hazy, & Lichtenstein (2010); (14) Runco (2007); (15) S. Sterling (2007); (16) Bowers (1995, 2006, 2012); (17) Fleener (2002); (18) Wood (2013); (19) Barron (1995); (20) Minati & Pessa (2006); (21) Montuori (2007); and (22) Craft (2010). Longer or more unusual phrases in quotation marks; almost all table material reflects direct quotations from sources as cited in the text of the paper.

DOMAIN SPECIFICITY, TRANSDISCIPLINARITY, AND COMPLEX REGENERATIVE CREATIVITY

Whereas some important creativity research focuses on domain-specific creativity (as discussed in Kaufman & Baer, 2005), other research supports the importance of inter- and transdisciplinary approaches to maximise creativity and cognitive diversity (see Ambrose & Cross, 2009; Kaufman & Baer, 2005). Regenerative creativity approaches creativity as a domain-general phenomenon and promotes inter- and transdisciplinary collaboration to increase cognitive diversity. Arguably, transdisciplinarity is key to productive, and we shall say regenerative creativity for big picture, regenerativity and sustainability issues. Some theorists warn against the risk of unintentional dogmatic traps of grand unifying theories and interdisciplinary team creativity (Baer, 2012, p. 166). One of the advantages of complexity-informed regenerating and regenerative creativity is a move away from "grand unifying theories" and towards richly textured and complex approaches that are in the process of ongoing self-replenishment. Pohl and Hadorn (2008) recommended transdisciplinary approaches to complex life-world problems, for example, in the environmental sciences.

Similar to the strengthening of ecosystems by biodiversity and the prevalence of complex intersections of high biological and cultural-linguistic diversities in global mega-diversity hot spots (Harmon & Maffi, 2002), regenerative creativity promotes innovative convergences of fruitful ecological and cultural pattern diversity "because the combination of remotely associated ideas can produce unpredictable, creative insights,...and the resulting idea mixtures produce better results in complex problem solving than would the collective contributions of homogenous groups" (Ambrose & Cross, 2009, p. 25). Complexity research demonstrates that increasing cognitive diversity enhances organisational vibrancy (Sargut & McGrath, 2011). Further, the emergent generativity and catalytic sustaining of complexity requires diversity and novel connections across domains. Moreno and Ruiz-Mirazo (2010) confirmed that open-ended growth of complexity in nature demonstrates resilience instead of fragility as a result of "new causal connections between domains that are not necessarily linked" (p. 74). One could argue that non-domain-specific (domain-general) creativity is a requisite for novel complexity; without this mechanism, complex systems would not be capable to carry out other transitions that involve a radically new way of organising their constituent and interactive processes (Moreno & Ruiz-Mirazo, 2010, p. 75).

Transdisciplinary contexts foster creativity for sustainability and regenerativity. Willetts and Mitchell (2007) found transdisciplinary approaches critical to the sustainability communities of practice. Krasny, Lundholm, and Plummer (2010) also found transdisciplinarity to be the most effective strategy at the creative intersection of complex resilience, learning, and environmental education. Regenerative design *requires* creativity to assemble diverse parts across social and natural contexts to produce innovation:

> If the transition is to be made--if the world is to make the change from the degenerative to the *regenerative* and thus sustainable mode--then priorities must change…With more interactions involved, more options available, and far more flexible technologies to deal with, regenerative design provides virtually unlimited opportunities for *invention* and for *devising varied ways of combining elements*. In such situations, analysis and deterministic methods usually provide knowledge of parts and mechanisms, but they rarely yield adequate answers. *Creativity enters the process in the key role of assembling diverse parts, often in unexpected ways.* (Lyle, 1994, pp. 37–38, 45, as quoted on the title page, emphasis added)

Lyle's insight that a holistic and flexible creativity can connect across silos and elements is compelling in its capacity to stop degenerative design and provoke a resurgence in regenerative designs.

Transdisciplinary creativity is also integral to sustainable solutions and regenerative design because it increases the diversity of learning communities and processes. Ambrose (2009) confirmed in particular that inter- and transdisciplinary creative groups produce more expansive divergence. Akkerman and Bakker's (2011) research on boundary objects and boundary crossing in educational contexts confirmed that the points of boundary (such as disciplinary boundary) crossing "are potential learning sources rather than barriers." Akkerman and Bakker also demonstrated that transdisciplinarity and domain-general creativity are critical for learning groups and communities of practice to remain dynamic, both in understanding the synthesis of decentred, multiple internal voices as well as in the dialogical multivoices and interactions of different minds expressing multiple meanings. Jackson (2003) has leveraged the metaphor of multiple, imbricated root mats growing and irrupting in polyvocal meaning with the term *rhizovocality* to express the possibilities of this rich interweaving, the diversity-as-resource approach to domain-general creativity and creative expression. Minati and Pessa (2006) emphasise complex and emergent systems must be designed to protect diversity and must consider diversity as a resource and not a problem, maintaining social multiplicity and the emergence of Collective Beings. Intersections of cultural practices open up *third spaces* that allow negotiation of meaning and hybridity (Akkerman and Bakker, p. 135); diversity is not just something to be managed, but something that incubates new learning and insight.

Minati and Pessa (2006) specified that, different from multi- or interdisciplinary approaches, "transdisciplinary approaches are taken when problems are considered between, across, and *beyond* disciplines, in a unitary view of knowledge" where the emphasis moves to the "dynamics between different levels of representation" (pp. 13-14). Minati and Pessa argued that transdisciplinary approaches are essential for complex phenomena in particular, for which classical mechanistic approaches are ineffective, and for which focusing on solutions for the problems rather than the people having the problems has only produced more difficult, new problems. By

stressing that "the study of single, isolated components is ineffective and unsuitable for problems carrying the complexity of emergent systems and processes," Minati and Pessa underscored transdisciplinary approaches for complex challenges (pp. 14-15). Montuori confirmed that transdisciplinary approaches will produce creative, contextualising, and connective inquiry combining rigor and imagination (2005).

From a complexity and chaotic order perspective, we know that teachers are more like provocateurs than controllers. They take the role of creating conditions and providing instigations for creative complexity, potentially producing bifurcation points and contexts open to ambiguity (Briggs & Peat 1999; Davis & Sumara, 2006; Hauk, 2011). School leaders can support self-organising schools: "self-organization and renewal sustain reform and improvement in a school through relationships, communication, sense making, and dialogue and conversation" (Bower, 2008, p. 116). Effective teachers embrace complexity, value creativity and inquiry, explore, adapt, and synthesize, and "maintain an open mind to avoid dogmatic insularity" (Ambrose, 2005, p. 292).

In summary, complex contexts require transdisciplinary approaches. These transdisciplinary approaches cross scales, increase innovation, solve at the system level, and increase divergence. They increase, honor, and harvest the creativity and insights of diverse learners and communities of practice, and support regeneration and renewal rather than degeneration in design.

COMPLEX EMERGENCE AND REGENERATIVE CREATIVITY

Regenerative creativity catalyses complex emergence. Emergence blossoms in cascading and interdependent, trans-scale, fractal integrities in nature. W. Berry (1981) in *The Gift of Good Land*, noted in "Solving for Pattern" that:

> … a good solution is good because it is in harmony with those larger patterns. …. A good solution acts within the larger pattern the way a healthy organ acts within the body ….[as]a part of its health. The health of organ and organism is the same, just as the health of organism and ecosystem is the same. And these structures of organ, organism, and ecosystem … belong to a series of analogical integrities that begins with the organelle and ends with the biosphere. (p. 134)

Another scholar terms these phenomena of interdependent wholenesses *self-generating gestalts*. Mathews (2008) considered these "an order of patterning in which elements are arranged into gestalts, and these gestalts fit into larger gestalts, and so on up the scale" (p. 56). Mathews noticed these emergent valences of wholeness are "self-generating rather than externally imposed."

Both Mathews and W. Berry noticed these self-generating integrities unfold and interdepend; they "cannot be exhausted or anticipated by any formula" (Mathews, 2008, p. 56), are not properly conveyed through philosophical contestation, adversarial dynamics, and dialectical critique, and are not exploitable or causal, as might be understood by mechanism or industrial thinking (W. Berry, 1981).

Ulanowicz (2002) argued that these complex patterns express an *ecological metaphysic* that conflicts in every assumption with a Newtonian worldview since ecological complexity is causally open and ecosystems are not deterministic machines but contingent and granular with historical, adaptive, organic, and interdependent propensities rather than causes. Goerner (1995) affirmed as well-supported "the image of an inextricably interwoven ecological universe – self-ordering...wholes," (p. 28). O'Sullivan reinforced T. Berry's description of the planetary context for creativity as recuperative, self-healing, and containing "special powers of regeneration" (1999, p. 205). Schuldberg (2007) echoed this language by describing the fractal quality and patterned chaos of everyday creativity as "reflecting their always original and self-renewing natures," (p. 58). These self-generating, self-similar, fractal emergences existing throughout nature constitute whole systems and can greatly enhance (and reinforce) regenerative creativity.

EARTH REGENERATION AS STRANGE ATTRACTOR FOR COMPLEX CREATIVITY

Earth regeneration in particular points us toward the sourcing of regenerative creativity in ecological complexity. Richards' research on creatives' resonance with fractal patterns from nature (2001a) prefigures the exploration for ecological and biocultural archetypes that my research explores (Hauk, 2007, 2011, 2013b, 2013c). Richards (2001a) researches the aesthetics of "bounded infinity from these domains of nature—and human nature—and the underlying laws that shape them" (p. 261) to understand if the beauty of the sublime and fractal forms of nature could increase flexibility and resilience to later life events. She also suggests that fractals awaken a new humanistic aesthetic, catalysing creative originality, hopefulness, an expansive sense of possibility and reverence for nature, interconnection, awareness of coevolution and compassion "in an evolving system of immense complexity and at time, of unpredictable sensitivity," catalysing "care for the health of this greater whole" of the earth system (pp. 89-90).

Consonant with Richards' findings, my research explores how exposure and inhalation and then perception of these complex patterns from nature increases intelligence and sparks regenerative creativity. Mathews identifies self-generating patterns arising from the interiority of nature—which she terms as conative gestalts—when internalised, as the sources of *gestaltic intuition*. This hearkens back to Cobb's (1977) insights regarding *The Ecology of Imagination in Childhood*: "Intuition, therefore, can be considered to be a type of 'seeing' stimulating in turn the organizing process we call imagination" (p. 47). Why is this so important? Wonder and the ability for novel juxtaposition and meaning-inference from multiple complex systems of embedded information is the source of innovation. Wonder can be described as the state of openness to novel system meshing:

> when it is maintained as an attitude, or a point of view, in later life, wonder permits a response of the nervous system to the universe that incites the mind

> to organize novelty of pattern and form out of incoming information. The ability of the adult to look upon the world with wonder is thus a technique and an essential instrument in the world of the poet, the artist, or the creative thinker (Cobb, 1977, p. 27).

Fauconnier and Turner (2002) identify the *conceptual blends* of two or more complex systems as resulting in multi-scope creativity from multi-scope integration networks. They argue that imagination along with identity and integration are "basic, mysterious, powerful, complex, and mostly unconscious operations…at the heart of even the simplest possible meanings" (p. 6). They demonstrate that "the value of even the simplest forms lies in the complex emergent dynamics [that imagination, identity, and integration] trigger in the imaginative mind." So our thinking and imagination and meaning-making are themselves complex phenomena, and the blending of complex concepts is at the heart of this emergent creative process.

Findings in neuroscience connect the importance of nature-inspired creativity and an attitude of wonder to the sciences as well. For example, Fauconnier and Turner connected metaphor and logic operating by the same complex conceptual blends (2002, p. 84). In *The Poetic Species*, Wilson argued that poets, like scientists, are engaged in enterprises of discovery bound by our relationship to other organisms (1984). Carson and Kelsh (1998) confirmed that a sense of meeting the unknown with primary senses, and having someone to share the experience with, are the critical process. Regenerative design scholar Lyle (1994) verified that "regenerative design involves both art and science not separately but merging together" (p. 38).

Some scholars who have offered a critique of novelty might object to the use of the discourse of innovation and creativity to expound the use of complex, nature-sourced pattern. For example, Bowers (1995, 2012) offered a thorough critique of the addiction to novelty that pervades Western scientism and can be credited with ecosystem and bioculture destruction. Bowers might prefer a reframe around regenerative ecological creativity to instead describe a return to indigenous strategies of deep interrelationship. He would say there is nothing novel about the topic of this chapter. I concur. I am describing a way of being that is natural, wholesome and inevitable for intergenerational, culturally and ecologically embedded cultures. Cultivating regenerative creativity and ecological complexity return us to the ecological and biocultural commons, return us to interdependent relationship with all participants (human and non-human), their relationships, and cycles of life (Bowers, 2006).

My curiosity resides in innovation, or perhaps we should call it earth-ovation, the call that Bowers (2006) names "the need to understand the complexity of the traditions we depend upon in daily life, and use as the basis for developing new and hopefully more ecologically friendly technologies, and advances in further securing a democratic and socially just society" (p. 159). I would even go so far as to extend Bowers' emphasis on intergenerational mentorship to suggest that learning from natural pattern is a way the Earth itself, continually in a state of generativity, can

mentor us. Additionally, as I suggest in the ethics portion of this paper, Bowers does point us toward a very fruitful form of creative, complex educational modeling when he suggests it is embedded cultures that can mentor as well.

EXTENDING BIOMIMICRY TO BIOCULTURAL-MIMICRY

I would propose extending biomimicry into the realm of bioculture to produce a construction of biocultural-mimicry in order to take up Bower's challenge to learn from (rather than take from) indigenous wisdom systems. Maffi and Woodley (2010) and the work of TerraLingua have established the connections between places of great biological and linguistic diversity, establishing the need to preserve and cultivate biocultural diversity as well as biodiversity. Bioculture represents the dense interweavings of human-nature, co-evolutionary cultures, and wisdom. We might call these cultural patterns that, like ecological patterns, serve as multi-scale fractal evidence of complex adaptive systems. In this case, these diverse and unique human cultural patterns and practices help maintain complex ecosystems in which they are embedded and with which they thrive. The traditional ecological knowledge (TEK), ethnobotany, and biocultural diversity movements offer deep examination and insights of some of these patterns, designs, and connections. Cajete (2000) articulated the indigenous wisdom of mutual experiencing: "the continual orientation of Native thought and perception toward active participation, active imagination, and active engagement with all that makes up natural reality… a part of the Earth mind" (pp. 27, 30). Cajete also explained:

> They experienced nature as part of themselves and themselves as part of nature. They were born of the earth of their place. …This is the ultimate definition of being 'indigenous' and forms the basis for a fully internalized bonding with that place. (pp. 186-187)

Citing traditions spanning more than 70,000 years, Cajete called this Native "ensoulment of nature… a *geopsyche*,…the inner archetypes in a place… that interaction between the inner and outer realities" (2000, pp. 186-187). This geopsyche, inner archetype, interior bonding, and co-presencing are another articulation of what Mathews (2008), as mentioned previously, calls gestaltic conativity.

T. Berry exhorted us: "The human is fulfilled in the earth. The earth is expressed in the human" (1999, p. xv). Modern articulations of this impulse include terrapsychology (Chalquist, 2010), place-based education (Gruenewald & Smith, 2008), as well as the resurgence of TEK (see, for example, Cajete, 2000). Additionally, ecopsychologists are actively engaged in distilling pattern languages not just of wild nature without humans, but "of deep and meaningful patterns of human interaction with nature, many of which emerged through tens if not hundreds of thousands of years in our evolutionary history" (Kahn, Ruckert, Severson, Reichert, & Fowler, 2010, p. 60).

SEEDS OF WISDOM

We are people, living in a time of seed-making. Seeds are distillations, often coated for endurance, taking the essence of the make-knowing and condensing it into a portable form. In the coming times of increasing turbulence and the unknown, a time of industrial culture's consequences, when it might be that what grew well or provisioned us before will no longer thrive, we have an opportunity to make seeds, to carry seeds, to teach people how to make and carry seeds of biocultural pattern and wisdom.

Seeds are an example of complexity compressed. Similar to algorithms for compressing computer files, language and thinking can also be compressed. Fauconnier and Turner (2002) spoke about compression in blending networks and how they operate on a surprisingly small set of relations rooted in fundamental human neurobiology. They saw conceptual blending as "an instrument of compression *par excellence*" and noted "one of the overarching goals of compression through blending is to achieve 'human scale' in the blended space, where a great deal of conscious manipulation takes place" (p. xiii). Rowland (1999) offered a three-faceted seed as a root metaphor for educational designing, learning, and systems, and found the chaos theory worldview as a potential convergence-creator between objective and constructive views.

The strategy and content of biocultural relations and insights (that are embedded in indigenous cultures' wisdom traditions) are examples of compressed wisdom seeds worth emulating. So the patterns of non-human nature as usually implied by biomimicry and also the patterns of human-nature relations from intact multigenerational nature-embedded wisdom systems are worthy of study and mimicry.

The traditional ecological knowledge (TEK) movement is a good example of capture and respect of indigenous biocultural wisdom (Martinez, 2012). The place-embedded specifics of biocultural wisdom are worthy of extensive study and learning, and so are the patterns and strategies that these collaborative, complex systems embody. Therefore, I propose that one area of study in regenerative creativity would be the archetypes or fractals of relationship and strategies of wisdom seeds offered by ecologically-embedded cultural folkways. This would provide, perhaps, a more detailed primer on the concept of "all my relations" (T. Berry, 1999, p. xiii). Extending Fauconnier and Turner (2002), learning how to think and design with poetry, folk sayings, mythology, and lifeways can carry generative, compressed double-scope creative blends. This can change our world and re-align us with the regenerative creative complexity of human-embedded cultures as well as help us learn to distill and carry forward life-giving pattern to share with the future earth system.

Parallel to the way that ecological fractals such as branching, vortex, hive, and flow can kindle regenerative creativity (Hauk, 2007, 2013b, 2013c), oral and indigenous wisdom systems and traditions will surface as biocultural fractals that

similarly promise to return our innovation to earthly regenerativity. In fact, some research indicates that creative works sparked by these ecological and biocultural system-coherent integrities might be necessarily more renewing and ethical.

INDICES OF SUCCESS

In terms of regenerative creativity, it is insufficient though important to provoke or enhance fluidity, flexibility, elaboration, and other traditionally recognised symptoms of creativity. The time of intense need beckons for what Madjar, Greenberg, and Chen (2011) name radical or divergent creativity rather than incremental creativity. Additional factors of group regenerative creativity will inspire literacy in the patterns of biocultural wisdom systems. These underlying relational archetypes might begin to expand traditional factor analysis of non-domain-specific creativity to include regenerativity to extend beyond conceptual blending strategies such as topology, pattern completion, integration, maximisation of vital relations, intensification, and maintenance of the web of links (Fauconnier & Turner, 2002). In other words, working with these archetypes does more than produce innovation *per se*, it produces ethical, regenerative innovation that in both content and form are creatively effective in the context of earth regeneration.

A direction for future work, currently underway, would be the development of a Transdisciplinary Regenerativity Index to help track and compare the complex adaptive systems regenerative potential of various creative products (Hauk, 2013a). Additionally, future work could extend this chapter's tracing of chaotic dynamics of creativity's multiscale emergence to include other complex adaptive and living systems elements. For example, how does regenerative creative emergence exhibit or how can it be optimised by distributed resilient systems biomimicry dynamics such as response diversity and ecological memory (Ryan, 2013).

ETHICAL CONDUCT IN REGENERATIVE CREATIVITY

The type of regenerative creativity cultivated by interaction/immersion in natural and biocultural pattern produces resilience and shifts values and ethics as well as catalyses and sustains restorative, novel, and adaptive solutions. This interposing time of glocal crisis requires all three of these fruits of regenerative creativity: ethical values shift, novel and restorative designs, and resilient cultures.

Regenerative creativity increases ethical conduct and produces designs that regenerate. Bowers (2006) made the case that alignment with complex natural cycles will produce cultural practices that are regenerative: "The importance of knowing the life cycles of the animals, plants, and other participants in the commons (bioregion)…leads to an emphasis being placed on cultural practices that are more attuned to the life-renewing characteristics of natural systems" (p. 96). What Bowers suggests is important. In fact, as he promises, and Mathews confirms, the fruit of this way of perceiving is moral reciprocity and ethical conduct. Bowers described it as

"a way of experiencing place in a way that combines a complex knowledge of local ecosystems with the practice of moral reciprocity" (p. 94).

Ecofractals and biocultural fractals form the core of ethical regenerative studies. Mathews (2008) proposed that time and *creative co-action* with the essential gestaltic integrities of nature, in fact, *induces moral commitment*. She suggested that co-active synergy induces the moral point of view. In particular, Mathews explored how creative connections with natural pattern can persist beyond moments of performance (as in activities such as the Council of All Beings). Mathews argued that, because creativity is a result of the internalised gestaltic patterns of nature, becoming imprinted with these patterns "will ensure that creative thinkers will incline towards a custodial attitude towards nature" (p. 57). In fact, Mathews highlighted the self-similarity between (re)generativity in nature, creativity, and an ethic of care. This case of self-similarity and fractality finds internalising the hidden order of the cosmos, "from within the calyx of nature," produces similar patterns of creativity and caring.

Mathews envisioned an educational system resulting from this insight:

> If people could be exposed in childhood to the kind of experiences that would result in their becoming imprinted with the inner organisational dynamics of nature, then this would produce a society of creative individuals whose activities in every field of praxis would be consistent with, and tributary to, the unfolding of nature….It would instead call on us to restructure education generally, at school level as well as at university level, so that all students would be routinely afforded opportunities for the kinds of experiences in nature that would result in their becoming imprinted with the inner organisational patterns of the cosmos. (pp. 57–58)

The vital practices of emotionally and socially engaged ecoliteracy confirm this connection between understanding how life is sustained by nature and the development of empathy for all life forms (Goleman, Bennett, & Barlow, 2012). It is in fact my proposal that experiences with these eco- and biocultural fractals would be at the very heart of earth regenerative studies.

Ulanowicz (2002) made a case for autocatalysis (autopoiesis, self-generation) in ecological complexity. He demonstrated mathematically that feedback loops from creative autopoiesis reinforce human-nature mutualism and continue to increase ethical alignment. He found that emergence and autocatalysis are related to a selective pressure (feedback loops) specifically from mutualism. These tend to shape and reinforce the "habits" of the system: "(1) Autocatalysis serves to increase the activities of all its constituents, and (2) it prunes the network of interactions so that those links that most effectively participate in autocatalysis tend to dominate over those that do not" (p. 8). One can interpret this aligning function of regeneration to include providing positive/directive pressure for mutualism and ethical alignment. Jardine (1998) suggested that an integrated curriculum with students learning to live with the self- "'organisation' *originating from things themselves*…their inviolable

integrity… generates a loving interest in the Earth and others" (pp. 80-81). Craft characterised this kind of ethically, socially, and ecologically aligned multiscale creativity as wise creativity (2010).

What I am describing as complex regenerative creativity increases ethical approaches to design and governance, for example in user-centred design, and protects against globalisation and imperialism. Complex adaptive systems mathematicians such as Minati and Pessa (2006) focused on complex emergence and demonstrate this shift. Design moves to a systems orientation and the user is no longer a passive consumer. They contended that, "now, on entering the systemic age, an age of complexity of learning, adaptive, self-organising systems, the crucial role of the user is no longer a cause of weakness, but of robustness" (p. 346). By solving problems for the people who are having them instead of focusing myopically on "the problem" out of its complex context, better and more ethical solutions arise. Further, they argued that complex and emergent learning approaches and designs protect both against imperialism and consent manipulation (p. 347). They found that, for emergence, systemic openness, and logical openness, through the mutual use of different levels of models:

> *The ethics of such an interaction between systems* regards the possibility of mutually influencing their respective behaviors, while respecting the systems' autopoietic processes i.e. *system identity…. An ethical process of interaction must be based on co-creation, co-designing whilst respecting the autopoiesis of the system.* Interaction systems are not assumed to simply establish a set of systems or lead to one dominating or enclosing the other. *Systems interact making emergent new multiple-systems, as in Collective Beings, and not just a new system.* (p. 348, emphasis all as in the printed original)

This mutual consent echoes the mutualism and reciprocity that Bowers mentions and the cultivation of an earth compassion that Mathews demonstrates.

Richards also found ethical values sourced from complex creativity (2001b). Specifically, Richards argued that holism and interconnectedness surface when the dynamic interactions of unique open systems of humans and creativity are the focus (2001b, p. 257). She "examines ways a brain organized according to principles of nonlinear dynamics (chaos theory) may initiate originality" (p. 263). She highlighted, sudden creative shifts "can begin to alter values and our way of life toward a sustainable world culture, and soften the multiple catastrophes for which we are now headed" (p. 263). Richards is suggesting that fractal/regenerative creativity encourages wholeness and connectedness that can move values into ethical alignment. She also suggested that chaotic creativity can build reserves for resilience in times of planetary system collapse.

In fact, the extension of biomimicry into biocultural-mimicry and regenerative creative engagement with these patterns can help avoid some of the detrimental decontextualisation of solo functional pattern plucking and lack of systems orientation to which biomimetics can fall prey. Neither biomimicry or biocultural-mimicry's

greatest call is to extend nature and bioculture as sites of colonisation, mining, and extraction for capitalist invention, production, and consumption. O'Sullivan warned that vision is required "that resists the corporate visions of an infinitely exploitable planet" (1999, p. 201). Craft (2010) echoed this concern, to avoid market-driven, growth-devoted *neophilia* for aligned and possibility-oriented wise creativity. It is possible that the systems-orientation and social and ecological insights of regenerative creativity and biocultural mimicry can in fact infuse a more grounded, contextualised, systems view into the practices of biomimetics and also extend its purview to human-cultural fusion. Montuori calls this kind of transdisciplinary approach to complex creativity, for example in the field of social creativity, a metaparadigmatic approach that contextualises and connects (2005, p. 155). The earlier discussion of the emergent effects of self-organisation from recursive regenerative creativity generating ecologies of creativity, cultures of innovation, empathy, and collaborative emergence are relevant here. S. Sterling (2007) saw these in complex emergence generating a "connective cultural consciousness" aligning with what some have theorised as the Great Transition, the Great Turning (Macy & Johnstone, 2012), and what O'Sullivan mentioned as T. Berry and Swimme's ecozoic era (1999). Similarly aligning with ethics of mutual reciprocity and care, both connective and collective, Dolby (2012) affirmed that these connections increase empathy and justice.

The very patterns of nature and nature-culture embed and evoke ethical conduct and regenerative processes. Re-embedding ourselves in the vital and vitalising patterns of Earth pushes us toward life-enhancing outcomes. Wangari Maathai (2010) named this rediscovering of the love of nature that animated our ancestors as the spark for reforesting entire ecosystems and transforming army troops to grove tenders.

CONCLUSION

Creativity can be complex and regenerative. As the earth works through us, the emissive and transformative dynamics of chaotic and complex creativity promise to generate and sustain the generation of new/ancient designs of emergent wholeness. In particular, transdisciplinary creativity opened in contexts of wonder and inspired by natural pattern promises to catalyse the human capacity for designing solutions that renew and replenish. These dynamic patterns from nature represent fractal archetypes from ecology as well as biocultural, human-nature collaboration. Renewing patterns create and awaken wholeness-making, diverse and divergent, regenerative design that aligns with an ethic of earth care, reciprocity, and mutualism.

We are called to optimise educational contexts for this life-giving and restorative complex creativity in order to nurture and awaken Earth designers and creators. We are invited to create and sustain edges of (learning) chaos where dense interactions between diverse creatives with sensitive dependence on initial conditions flourish in far from equilibrium states—including divergence-nurturance, flow and purpose, and a capacity for ambiguity. These spark amplifying feedback loops and sustain

creative emergences. Together, our collective creativity emerges as a fractal mirror of nature's generative wholeness.

REFERENCES

Akkerman, S. F. & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81*, 132–169.

Ambrose, D. (2005). Creativity in teaching: Essential knowledge, skills, and dispositions. In J. C. Kaufman & J. Baer (Eds.), *Creativity across domains: Faces of the muse* (pp. 281–298). Mahwah, NJ: Erlbaum.

Ambrose, D. (2009). *Expanding visions of creative intelligence: An interdisciplinary exploration.* Cresskill, NJ: Hampton Press.

Ambrose, D. (2012). An interdisciplinary flight over dogmatic socioeconomic, political, ideological, and cultural terrain. In D. Ambrose & R. J. Sternberg (Eds.), *How dogmatic beliefs harm creativity and higher-level thinking* (pp. 64–76). New York, NY: Routledge.

Ambrose, D. & Cross, T. (Eds). (2009). *Morality, ethics, and gifted minds*. New York, NY: Springer.

Bache, C. M. (2008). *The living classroom: Teaching and collective consciousness*. Albany, NY: State University of New York Press.

Baer, J. (2012). Unintentional dogmatism when thinking big: How grand theories and interdisciplinary thinking can sometimes limit our vision. In D. Ambrose & R. J. Sternberg (Eds.), *How dogmatic beliefs harm creativity and higher-level thinking* (pp. 157–170). New York, NY: Routledge.

Bar-Cohen, Y. (Ed.). (2006). *Biomimetics: Biologically inspired technologies*. Boca Raton, FL: Taylor & Francis.

Bar-Cohen, Y. (Ed.). (2012). *Biomimetics: Nature-based innovation*. Boca Raton, FL: CRC Press.

Barron, F. (1995). *No rootless flower: An ecology of creativity*. Cresskill, NJ: Hampton Press.

Berkes, F., Colding, J., & Folke, C. (2003). *Navigating social-ecological systems: Building resilience for complexity and change*. Cambridge, England: Cambridge University Press.

Benyus, J. M. (2002). *Biomimicry.* New York, NY: Harper Perennial.

Berry, T. (1999). Foreword. In E. O'Sullivan, *Transformative learning: Educational vision for the twenty-first century* (pp. xi–xv). New York, NY: Zed/University of Toronto.

Berry, W. (1981). *The gift of good land: Further essays cultural & agricultural*. San Francisco, CA: North Point Press.

Bower, D. (2008). Leadership and the self-organizing school. In B. Després (Ed.), *Systems thinkers in action: A field guide for effective change leadership in education* (pp. 109–121). Lanham, MD: Rowman & Littlefield Education.

Bowers, C. A. (1995). *Educating for an ecological sustainable culture: Rethinking moral education, creativity, intelligence, and other modern orthodoxies*. Albany, NY: State University of New York Press.

Bowers, C. A. (2006). *Revitalizing the commons: Cultural and educational sites of resistance and affirmation*. Lanham, MD: Lexington Books.

Bowers, C. A. (2012). The challenge facing educational reformers: Making the transition from individual to ecological intelligence in an era of climate change. In D. Ambrose & R. J. Sternberg (Eds.), *How dogmatic beliefs harm creativity and higher-level thinking* (pp. 112–122). New York, NY: Routledge.

Briggs, J., & Peat, F. D. (1989). *Turbulent mirror: An illustrated guide to chaos theory and the science of wholeness*. New York, NY: Harper & Row.

Briggs, J. & and Peat, F. D. (1999). *Seven life lessons of chaos: Spiritual wisdom from the science of change.* New York, NY: Harper Collins.

Cajete, G. (2000). *Native science: Natural laws of interdependence*. Santa Fe, NM: Clear Light.

Capra, F. (1996). *The web of life: A new scientific understanding of living systems*. New York, NY: Anchor.

Capra, F. (2002). *The hidden connections: A science for sustainable living*. New York, NY: Anchor.

Carson, R. L., & Kelsh, N. (1998). *The sense of wonder*. New York, NY: HarperCollins.

Chalquist, C. (2010). *RebEarths: Conversations with a world ensouled*. Walnut Creek, CA: World Soul Books.

Christensen, B. (2005). Emerging participative exploration: Consultation as research. In R. Stacey & D. Griffin (Eds.), *A complexity perspective on researching organizations:Taking experience seriously* (pp. 78–106). New York, NY: Routledge.

Cobb, E. (1977). *The ecology of imagination in childhood*. Dallas, TX: Spring.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). New York, NY: Routledge.

Craft, A. (2010). Possibility thinking and wise creativity. In R. A. Beghetto & J. C. Kaufman (Eds.), *Nurturing creativity in the classroom* (pp. 289–312). Cambridge, England: Cambridge University Press.

Crutzen, P. J. (2006). The "Anthropocene." In E. Ehlers & T. Krafft (Eds.), *Earth system science in the Anthropocen*e (pp. 13–18). Heidelberg, Germany: Springer.

Csikszentmihalyi, M. (1999). Impliciations of a systems perspective for the study of creativity. In R. J. Sternberg (Ed.), *The handbook of creativity* (pp. 313–335). Cambridge, England: Cambridge University Press.

Cumberlidge, C., & Musgrave, L. (2007). *Design and landscape for people: New approaches to renewal.* London, England: Thames & Hudson.

Davis, B., & Sumara, D. J. (2006). *Complexity and education: Inquiries into learning, teaching, and research*. Mahwah, NJ: Erlbaum.

Dolby, N. (2012). *Rethinking multicultural education for the next generation: The new empathy and social justice*. New York, NY: Routledge.

Doll, W. E., Fleener, M. J., & St. Julien, J. (Eds.) (2005). *Chaos, complexity, curriculum and culture: A conversation*. New York, NY: Peter Lang.

Fauconnier, G., & Turner, M. (2002). *The way we think: Conceptual blending and the mind's hidden complexities*. New York, NY: Basic Books.

Fleener, M. J. (2002). *Curriculum dynamics: Recreating heart*. New York, NY: Peter Lang.

Goerner, S. (1995). Chaos, evolution, and deep ecology. In R. Robertson & A. Combs (Eds.), *Chaos theory in psychology and the life sciences* (pp. 18–38). Mahwah, NJ: Erlbaum.

Goertzel, B. (1995). Belief systems as attractors. In R. Robertson & A. Combs (Eds.), *Chaos theory in psychology and the life sciences* (pp. 123–134). Mahwah, NJ: Erlbaum.

Goldstein, J., Hazy, J. K., & Lichtenstein, B. B. (2010). *Complexity and the nexus of leadership: Leveraging nonlinear science to create ecologies of innovation*. New York, NY: Palgrave Macmillan.

Goleman, D. (2009). *Ecological intelligence: How knowing the hidden impacts of what we buy can change everything*. New York, NY: Broadway Books.

Goleman, D., Bennett, L., & Barlow, Z. (2012). *Ecoliterate: How educators are cultivating emotional, social, and ecological intelligence*. San Francisco, CA: Jossey-Bass and the Center for Ecoliteracy.

Gruenewald, D. A. & Smith, G. A. (Eds.). (2008). *Place-based education in the global age: Local diversity*. New York, NY: Routledge.

Gunderson, L. H., Allen, C. R. & Holling, C. S. (Eds). (2010). *Foundations of ecological resilience.* Washington, DC: Island Press.

Harmon, D. & L. Maffi (2002). Are linguistic and biological diversity linked? *Conservation Biology in Practice 3,* 26–27.

Hauk, M. (2007). *Gaian mind: Natural patterns nurturing creative approaches for Earth regeneration* (Unpublished master's thesis). Holy Names University, Oakland, CA.

Hauk, M. (2011). Compost, blossom, metamorph, hurricane - Complexity and emergent education design: Regenerative strategies for transformational learning and innovation. *Journal of Sustainability Education 2*. Retrieved from http://www.jsedimensions.org/wordpress/wp-content/uploads/2011/03/Hauk2011.pdf

Hauk, M. (2013a). *The Earth beyond sustaining: Assessing and designing for regeneration by developing the Transdisciplinary Regenerativity Index.* Paper presented at the Society for Chaos Theory in Psychology and the Life Sciences, Portland, OR. *Abstracts to the 23rd Annual International Conference, Portland OR.* Abstract retrieved from http://www.societyforchaostheory.org/conf/2013/abstracts.pdf

Hauk, M. (2013b, April). Five fractal geometries for creative, sustainable, and just educational design. In S. Gerofsky (Chair), *The geometries of liberation: The hidden wealth of patterns and materials outside the grid.* Interactive symposium conducted at the American Educational Research Association Conference, San Francisco, CA. Paper retrieved from http://www.aera.net/Publications/OnlinePaperRepository/AERAOnlinePaperRepository/tabid/12720/Default.aspx

Hauk, M. (2013c). Leaf, fire, river, hive, and storm: Catalyzing regenerative education in small group collaboration through complex ecological fractals. Paper presented at the Society for Chaos Theory in Psychology and the Life Sciences, Portland, OR. *Abstracts to the 23rd Annual International Conference, Portland OR.* Abstract retrieved from http://www.societyforchaostheory.org/conf/2013/abstracts.pdf

Jackson, A. Y. (2003). Rhizovocality. *International Journal of Qualitative Studies in Education. 16,* 693–710.

Jardine, D. W. (1998). *To dwell with a boundless heart: Essays in curriculum theory, hermeneutics, and the ecological imagination*. J. L. Kinchelow & S. R. Steinberg (Series General Eds.), *Counterpoints: Studies in the Postmodern Theory of Education, 77*. New York, NY: Peter Lang.

Kahn, P., Ruckert, J. H., Severson, R. L., Reichert, A. L., & Fowler, E. (2010). A nature language: An agenda to catalog, save, and recover patterns of human–nature interaction. *Ecopsychology, 2,* 59–66.

Kaufman, J. C., & Baer, J. (Eds.).(2005). *Creativity across domains: Faces of the muse*. Mahwah, NJ: Erlbaum.

Kellert, S. (2005). *Building for life: Designing and understanding the human-nature connection*. Washington DC: Island Press.

Krasny, M. E., Lundholm, C. & Plummer, R. (2010). Resilience in social–ecological systems: The roles of learning and education. *Environmental Education Research, 16*(5–6), 463–474.

Lyle, J. T. (1994). *Regenerative design for sustainable development*. New York, NY: Wiley.

Macy, J. (1991). *Mutual causality in Buddhism and general systems theory: The dharma of natural systems*. Albany, NY: State University of New York Press.

Macy, J. & Johnstone, C. (2012). *Active hope: How to face the mess we're in without going crazy*. Novato, CA: New World Library.

Madjar, N., Greenberg, E., & Chen, Z. (2011). Factors for radical creativity, incremental creativity, and routine, noncreative performance. *Journal of Applied Psychology, 96,* 730–743. doi:10.1037/a0022416

Maffi, L., & Woodley, E. (2010). *Biocultural diversity conservation: A global sourcebook*. London, England: Earthscan.

Manuel-Navarrete, D., Kay, J. J., & Dolderman, D. (2004). Ecological integrity discourses: Linking ecology with cultural transformation. *Human Ecology Review, 11*, 215–228.

Margulis, L. (2004). Gaia by any other name. In S. Schneider, J. R. Miller, E. Crist & P. J. Boston (Eds.), *Scientists debate Gaia: The next century* (pp. 7–12). Cambridge, MA: MIT Press.

Martinez, D. (2012, August). *How western ecologists and indigenous knowledge-holders from two standalone epistemologies can find common ground and join forces in ecological restoration and conservation biology.* Paper presented at the meeting of the Ecological Society of America (ESA), Portland, OR.

Mason, M. (Ed.) (2008). *Complexity theory and the philosophy of education*. Malden, MA: Wiley-Blackwell.

Mathews, F. (2008). Thinking from within the calyx of nature. *Environmental Values, 17,* 41–65. doi:10.3197/096327108X271941

Maubossin, M. J. (2011, September). Embracing complexity. *Harvard Business Review 89* (9), 88–92.

Minati, G. & Pessa, E. (2006). *Collective beings*. New York, NY: Springer.

Montuori, A. (2005). Gregory Bateson and the promise of transdisciplinarity. *Cybernetics and Human Knowing, 12,* 147–158.

Moreno, A. & Ruiz-Mirazo, K. (2010). The maintenance and open-ended growth of complexity in nature: Information as decoupling mechanism in the origins of life. In F. Capra, A. Juarrero, P. Sotolongo, & J. van Uden, *Reframing complexity: Perspectives from the North and South* (pp. 59–77). Litchfield Park, AZ: Emergent.

Murphy, K. (2011, August 29). *In Seattle, work starts on 'greenest' office building*. Los Angeles Times. Retrieved from http://www.latimes.com/news/nationworld/nation/la-na-green-building-20110830,0,5790282.story

Nolet, V. (2009). Preparing sustainability-literate teachers. *Teachers College Record, 111*(2).

O'Sullivan, E. (1999). *Transformative learning: Educational vision for the twenty-first century*. New York, NY: Zed/University of Toronto.

Pohl, C. & Hadorn, G. H. (2008). Methodological challenges of transdisciplinary research. *Natures Sciences Sociétés, 16,* 111–121. DOI: 10.1051/nss:2008035

Richards, R. (2001a). A new aesthetic for environmental awareness: Chaos theory, the beauty of nature, and our broader humanistic identity. *Journal of Humanistic Psychology, 41* 59–95.

Richards, R. (2001b). Millennium as opportunity: Chaos, creativity, and Guilford's Structure of Intellect model. *Creativity Research Journal*, *13,* 249–265.

Rowland, G. (1999). *A tripartite seed: The future creating capacity of designing, learning, and systems*. Cresskill, NJ: Hampton Press.

Runco, M. A. (2007). *Creativity: Theories and themes – research, development and practice*. Amsterdam, The Netherlands: Elsevier Academic Press.

Ryan, C. (2013). Critical agendas: Designing for sustainability from products to systems. In S. Walker & J. Giard (Eds.), *The handbook of design for sustainability* (pp. 408–427). New York, NY: Bloomsbury.

Sargut, G. & McGrath, R. G. (2011-September). Learning to live with complexity. *Harvard Business Review, 89,* 67–76.

Sawyer, R. K. (2010). Individual and group creativity. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge handbook of creativity* (pp. 366–380). New York, NY: Cambridge University Press.

Schuldberg, D. (2007). Living well creatively: What's chaos got to do with it? In R. Richards (Ed.), *Everyday creativity and new views on human nature: Psychological, social, and spiritual perspectives*. Washington DC: American Psychological Association.

Stacey, R. & Griffin, D. (2005). *A complexity perspective on researching organizations: Taking experience seriously*. New York, NY: Routledge.

Sterling, A. (2003). Human creativity and chaotic dynamics. In D. Ambrose, L. M. Cohen, & A. J. Tannenbaum (Eds.), *Creative intelligence: Toward theoretic integration* (pp. 147–178). Cresskill, NJ: Hampton Press.

Sterling, S. (2009). Riding the storm: Towards a connective cultural consciousness. In E. J. Wals (Ed.), *Social learning towards a sustainable world: Principles, perspectives, and praxis* (pp. 63–82). Wageningen, The Netherlands: Wageningen Academic.

Taylor, M. M. (2011). *Emergent learning for wisdom*. New York, NY: Palgrave Macmillan.

Thomas, D. & Brown, J. S. (2011). *A new culture of learning: Cultivating the imagination for a world of constant change*. New York, NY: Soulellis.

UN Economic Commission for Europe. (2011). Learning for the future: Competences in education for sustainable development. United Nations Economic and Social Council. Report ECE/CEP/AC.13/2011/6. Retrieved from http://www.unece.org/fileadmin/DAM/env/esd/6thMeetSC/Learning%20for%20the%20Future_%20Competences%20for%20Educators%20in%20ESD/ECE_CEP_AC13_2011_6%20COMPETENCES%20EN.pdf

Ulanowicz, R.E. (2002). Toward quantifying semiotic agencies: Habits arising. *Journal of Semiotics, Evolution, Energy and Development 2,* 38–55.

Van Der Ryn, S. & Cowan, S. (1996). *Ecological design* (tenth anniversary edition). Washington, DC: Island Press.

Van Der Ryn, S. & Cowan, S. (2007). Ecological design: A ten-year retrospective (Introduction). In *Ecological design* (10th anniversary edition). Washington, DC: Island Press.

Waltner-Toews, D., Kay, J., & Lister, N.-M. E. (Eds). (2008). *The ecosystem approach: Complexity, uncertainty, and managing for sustainability*. New York, NY: Columbia University Press.

Widhalm, B. (2011). Educators as architects of living systems: Designing vibrant learning experiences beyond sustainability and systems thinking. *Journal of Sustainability Education 2*. Retrieved from http://www.jsedimensions.org/wordpress/content/educators-as-architects-of-living-systems-designing-vibrant-learning-experiences-beyond-sustainability-and-systems-thinking_2011_03/

Willetts, J. & Mitchell, C. (2007). Learning to be a "transdisciplinary" sustainability researcher: A community of practice approach. In ANZSYS Conference, R. Attwater, & J. Merson (Eds.), *Sustaining our social and natural capital: Proceedings of the 12th ANZSYS Conference* (pp. 398–405). Mansfield, MA: ISCE.

Wilson, E. O. (1984). *Biophilia*. Cambridge, MA: Harvard University Press.

Wood, J. (2013). Meta-designing for paradigm change: An ecomimetic, language-centred approach. In S. Walker & J. Giard (Eds.), *The handbook of design for sustainability* (pp. 428–445). New York, NY: Bloomsbury.