

Uncovering Science in Adult Education: Welcome Complexity Theory

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Abstract: The transdiscursive concepts of complexity science concepts, already implicit in adult education, should be made explicit to promote transformative theoretical developments in adult education and empower adult learners and adult education academics to access and interpret this knowledge for themselves.

Theoretical Gap in Adult Education Leaves Room for Complexity Science

The adult education philosophies as traditionally defined by Elias & Merriam (2005) mention natural science as follows: A classical liberal arts education incorporates natural science under natural philosophy, but this tradition is negatively identified with elite education. Behaviorism is a *psychological system* arising from experimental research using the scientific method and sharing assumptions with the philosophical traditions of materialism, scientific realism, and positivism. Its restrictive view of humanity makes it unpopular. Since education normally relies on psychology to translate and reframe natural science for them, this behaviorist philosophy represents what many educators know and believe about science. Humanism has a clear strain of protest against science as threatening to humanity, being held responsible for the industrial revolution, the related growth of capitalism and creation of modern weapons. Analytic philosophy arose from scientific realism: truth exists only in correspondence between mental idea and external reality. Critical adult educators criticize analytic philosophy for failing in the same ways as liberalism: neglecting social, political and economic contexts and their related problems. Postmodernism looks back to progressivism and sees *primarily* science, which it identifies as a primary cause of current social problems and defines only in terms of the assumptions of empiricism and rationalism, stated as the products of Western culture (Doll, et al, 2005; Elias & Merriam, 2005; Kuklick, 2001). The existing theoretical gap is a legitimate place for complexity science.

Bases for Proposing the Use of Complexity Science in Adult Education

For any educator who practices in a science based discipline such as the health care professions, it is necessary to have an appreciation of natural sciences. This includes the beliefs that natural sciences make valuable contributions to our understanding of the world we live in and that the application of scientific findings can improve people's lives. To science accustomed eyes, the world of adult education philosophy appears hostile, since the most prevalent current philosophies do not embrace natural science or they explicitly reject it.

As neuroscience makes its way into education theorizing, it will be useful to have a philosophy that allows direct connection with natural science. Neurophilosophy exists at this interface (Churchland, 2002) Churchland (2002, p. 39 - 40) now proposes that since philosophy integrates theory across domains it belongs on a continuum with science, involving a pragmatist re-describing of metaphysics as that which addresses questions in their pre-scientific phase. She notes this is consistent with the ideas of Charles Sanders Peirce and W.V.O. Quine and is a view antithetical to a priori philosophy, which believes that pure reason and reflection can resolve questions without scientific exploration.

Overview of Complexity Science

Complexity science is the study of complexity theory, a form of systems thinking. Arising in biochemistry the theory described systems as living organisms and social systems, integrated wholes whose properties were determined by the relationships among their parts. Systems thinking meant contextualizing so that an organism was always understood as existing through relationships within the greater whole (Capra, 1996, p.27). This holistic, organismic perspective which contrasts with older mechanistic models of science emerged simultaneously in all sciences and other disciplines in the 20th century. This is not vitalism, which also asserts holism but requires that a non-physical entity, or force must exist to understand life. Organismic biology says that the *patterns of relationship* within the physical structures of living systems *are what make them whole*. This pattern of relationship has been refined to the concept of *self-organization* in which systems consist of complex networks that communicate, self-replicate, and recreate themselves in new forms. The essential properties of an organism are properties of the whole, not possessed by the parts, so life cannot be studied through reductive methods. The theory assumes all complex systems have structural and behavioral commonalities and can be modeled mathematically (Capra, 1996). Therefore a neural networks scientist might theorize productively with an evolutionary biologist, an economist, a business manager, and an adult educator.

Biology developed the concept of self-organization. Both physical and biological systems (sand grains, chemical reactants, cells in tissues, schools of fish) are self-organized through complex patterns. These self-organizing systems obtain their order and structure through something inherent to themselves, interactions based on some mutual understanding by parts that results in patterns, without the need for external directing influences. Systems that lack self-organization or the capability to self-organize can have it imposed (Camazine, Deneubourg, Franks, Sneyd, Theraulaz, & Bonabeau, 2001). Self organization is perhaps the most central concept of systems thinking. "The pattern of *life* ... is a network pattern capable of self-organization" (Capra, 1996, p. 83). So living systems are self-ordering, but not all self-ordering systems are living.

Systems thinking emerged in physics as quantum physics with the realization that matter reduces to waves of probabilities at the subatomic level. Heisenberg's uncertainty principle expressed that subatomic particles cannot be understood in isolation and require understanding of their interrelations. These probabilities are determined by the dynamics of the whole system (Prigogine, 1996), an idea later extended to the concepts of perception in psychology and communities in ecology. Prigogine enhanced understanding of self-organization through work in physics on dissipative structures where change and stability co-exist, paradoxically. These structures exist far from equilibrium states, in high degrees of chaos. Living systems are dissipative systems, but not all dissipative systems are living. Prigogine saw the connection with non-linearity and used non-linear equations to describe his observations. Through this work we now understand that self-organizing systems create novel structures and new forms of behavior in the processes of development, learning, and evolution. What Prigogine discovered is that self-organizing systems, far from equilibrium, reach a critical point of chaos at which they spontaneously self-organize into a new, ordered pattern. They can evolve by transforming themselves into new structures with greater complexity (Prigogine & Stengers, 1984).

The mathematical theory which explains the non-linear network connectedness of self-organizing systems described by complexity theory is most often called dynamic systems theory, two important branches of which are chaos theory and theory of fractals. It is a qualitative

mathematics of relationships and patterns. Because prediction of non-linear equations is often impossible, qualitative analysis has come to be preferred over quantitative in these cases. Non-linear systems consist of self-reinforcing feedback loops which amplify the effects of change, so that small changes can result in large effect sizes. This creates the instability that leads to sudden emergence of new forms in transformative self-organization. Movement within a non-linear system's feedback loops occurs along a trajectory, an inward spiral, called by the metaphorical name attractor because the fixed point at the center of a coordinate system appears to 'attract' the trajectory. The complexity of such irregular shapes which occur in the natural world is described by the Mandelbrot's mathematics of fractal geometry which, through computer modeling, has allowed us to see that the self-similarity of pattern within pattern exists throughout nature. These richly complex structures are ordered by a few simple rules which can give rise to complex shapes (Capra,1996; Schroeder, 1991).

With the discovery of new mathematics and more powerful computers, intricate patterns of intertwined webs could be analyzed and theorizing exploded as scholars from all disciplines, biology to economics, communicating through mathematics and metaphor at places like the Santa Fe Institute (SFI), strove to apply an evolving understanding of how life is organized (Waldrop,1992). Through integration of all the strains of research that have just been described, then testing and application transdisciplinarily at private think tanks and government research centers, systems thinking is now pervasive in our world.

Unfortunately, complexity thinking is often presented in ways that suggest a metadiscourse. This is challenged as misconception by arguing that complexity science is not an explanatory system. Part of its appeal has been the enhanced recognition of similarities across disparate phenomena, suggesting answers to questions that rely on analogy and metaphor. It is transphenomenal, transdisciplinary, and interdiscursive. It has to be all of these because it studies phenomena at the level of emergence. Its great value lies in its connective power making conversation possible between disparate perspectives often leading to unimagined developments. To attain the status of metadiscourse would freeze discursive activity and decrease connectivity, which would suggest a dying system (Davis & Phelps, 2005; Davis & Sumara, 2006).

A second strain of criticism is posed indirectly by feminist debates about science in general and evolutionary biology in particular. Some of the arguments are defused by new biological findings requiring modifications to Darwin's original theses (Kauffman, 1993). Other lines of argument have been challenged as logical fallacy in that theory about organic life cannot be invalidated by arguments noting its congruence with aspects of capitalism. Likewise, to equate Darwinian Theory with social Darwinism is a fallacy of logic. There is general agreement on all sides about the data regarding female behavior in sexual choice. The debates arise around the meaning of this behavior. Since meaning can only be interpreted and not empirically demonstrated with animal behavior, any interpretation might be on equal footing with Darwin's and all theorizing is welcomed. The theorizing can not invalidate evolutionary theory (Vandermassen,2004). More interesting are the discussions about a feminist science. While acknowledging the presence of misogyny in science, Longino (2005) declares that calls for a women's values inspired interactionist science will not be taken seriously because holistic, interactionist research programs (complexity science) already exist, albeit in the hands of men who predominate in science. She notes that claims to a feminist science characterized by complexity, interaction and holism, are branded as weak and non-mathematical, presumably because this 'science' is sourced in a feminist perspective rather than in science and mathematics (as is the comparable complexity science). Longino expresses support for a feminist congruent

model, chosen deliberately based on political considerations. This is Edelman's neurobiology model, which replaces a linear brain model with a much more complex and interactive one of a self-organizing and self-modifying unit. Desirable because it allows for agency and validates subjective experience, it is praised elsewhere for producing research which confounds the often assumed immutability of sex and sexual difference presented in some cultural theories.

How Complexity Relates to Adult Education Theory

Complexity science concepts are implicit in adult education, just as they flow through popular culture. They should be made explicit because 1) the transdiscursive nature of complexity science could promote transformative theoretical developments in adult education and 2) by identifying a continually evolving source of this knowledge in science, adult learners and adult education academics are empowered to access and interpret this knowledge for themselves.

Grounded in pragmatism, a distinctively American philosophy rooted in the writings of Charles Peirce, progressives identified human beings as naturally evolving in concert with their evolving world. These ideas came forth in education through John Dewey and vestiges remain in social constructivism and radical educational philosophies. Dewey is the source of critical and reflective thinking and service education. But today in educational philosophy the progressive embrace of science is gone (Doll, et al, 2005; Elias & Merriam, 2005; Kuklick, 2001)

Complexivists in the field of education (Doll et al, 2005) are returning to Charles Peirce for philosophical inspiration. Peirce rejected Cartesian rationalism and believed that all learning is prefaced by the desire to learn, making method inconsequential, and requiring education to bring forth the struggles of one's own imaginative process using reflection. With pragmatism, the value of an idea lies in the consequences occurring when the person acts on the idea. Action and doing, consequences and purposes are reiterated in the process of personal evolution. Dewey drew heavily on Peirce in developing his ideas about praxis and his conception of logic as a matrix of inquiry, with forms and standards emerging rather than being imposed from outside (not unlike a complex neural network). Applying the language of complexity, pedagogy is framed as performative process and curriculum is emergent. Fluid habits in dynamic interaction between learner and educator create new knowledge and new forms (Davis & Sumara, 2006; Doll et al, 2005).

The other philosophical influence comes from post-perspectives. Post-structural critiques resonate with complexivist notions of self-organization, self-maintenance, mutual specification of agents, adaptation, and nested organization which fit well when the system of interest is culture, body politic, and bodies of knowledge (Davis & Sumara, 2006; Wells, 2004). The other strain is constructive postmodernism, which rejects concepts of an essential human nature and of reason as an a priori human capacity. It denies that social progress can be achieved by applying social science theories to institutions and distrusts metanarratives. Postmodernism endorses heterogeneity, difference, fragmentation, and indeterminacy. Notably these are qualities possessed by living systems as defined by complexity science. As postmodern inquiry, complexity science is a perspective on meaning, not a collection of techniques. Science (and complexity by extension) is redefined as meaning system, in close alignment with spirituality, relationship, and interdependence. The logic of relationship and experience take precedence over logic as abstract form (Davis & Sumara, 2006; Doll, et al, 2005; Wells, 2004).

For a complexivist, learning consists of simultaneous biological and behavioral (therefore *structural*) transformations in the learner. Structure in this biological sense is paradoxical,

encompassing cause and accident, completion and process concurrently. Learning occurs due to the learner's unique biological/experiential structure. Learning is a highly individual recursive and elaborative process. It is activated through disturbances or irritations, so teaching can stimulate learning through intentional disturbances. The structure of a living system is unique and embodies its history. Many of its traits can never be known or replicated. So a learner is a complex unity capable of adapting to new situations presented in a dynamic environment. 'Learner' is no longer just the individual being, but can be represented at many systems levels, even many at one time, so that cells may be learners at the same time that a group of community members are learners, and they can be learning as individual systems or as part of a complex interacting system (Davis & Sumara, 2006; Doll, et al, 2005).

Assuming that learning is about evolving to greater complexity via pattern formation, it is essential to understand the ways organisms achieve pattern formation. Self-organization is often preferred. It requires few resources or rules. Especially in large groups, the alternatives are extremely difficult to use. Leadership by central authority requires personal abilities and resources that are rarely available. Blueprints are in short supply and require instructions, so demands for native cognitive ability are high. Recipes only work for individual projects and impede cooperative effort. Templates are rare, so we need to accept that only through engagement with our environment and other people can we 'see' the forms to which we must respond and know what our contribution is to be. It is no wonder that natural selection prefers self-organization (Camazine, et al, 2001, p. 63-67). Control is embedded within situations, arising naturally and in complex forms out of simple interactions that make up life. This control is lively, dynamic, highly variable and we help to create it throughout interactions (Wells, 2004; referencing Doll, p.202).

Expanding on traditional understanding of radical and critical adult education, Tisdell & Taylor (2001) present the five most prevalent adult education philosophies as overlapping transdiscursive categories weaving various threads of critical tradition with each other and with humanism, building on the earlier traditions of liberalism and progressivism. Complexity science builds on the same earlier traditions. Since living systems evolve toward greater complexity and thrive on connectedness, complexivist education would *not* seek to develop autonomy, making it consistent with the feminist inspired relationally-driven philosophies. The complexivist focus is neither purely individual or social-cultural, but rather the points of interaction where individual and context meet. It resonates with writing about spirituality in adult education (English, Fenwick & Parsons, 2003; Palmer, 2004; Tisdell, 2003).

The pedagogy of creating disturbances and the 'post' perspective thread in complexity are consistent with post structural feminist and feminist emancipatory pedagogies. The post-structural (Tisdell, 1998) has several well-developed points of overlap with complexity. Both concern themselves with structures in their dynamic state, interested in the paradoxical tensions that keep them changing and therefore alive. The complexivist approach, in promoting pattern formation, disrupts hierarchies in favor of self-organization. Fostering greater complexity as life giving it prefers strategies that increase diversity. Its understanding of co-creation/co-evolution of learner and environment makes transformation inevitable. Trajectory, time course, and outcome remain unpredictable. The educator intending to effect social change, informed by understanding of pattern formation and self-organization, knows that creating disturbance will result in some kind of learning, but how and in whom and with what result will be unknown.

At every level of organization (human body, learner 'self', classroom, community, workplace) connectivity is required for internal coherence and to sustain life. We are connected

to ourselves, self-reflexively, and to the world, in a sense as co-creators. My mindset can disconnect me from the world, because my conceptualizations about others determine my connections with them. It is impossible to self-regulate when disconnected from the world because there is no feedback, which is necessary over time and space. My connectivity at multiple system levels creates its own patterns, which help shape other patterns, and the changing creates a rhythm. So there is nothing static about health or teaching. The essence of life in our natural world is movement arising from connections. Making invisible connections manifest can increase health, and adaptation happens within some midrange of connectivity. Sometimes the demands for connectivity for health at a higher system level, like a workplace organization, create an unhealthy degree of connection at the personal and even body level. These effects can be mitigated when leadership in a living system is shared, distributed and circulated (Stanley, 2006). By using one's own connectivity with students, revealing connections to self, the adult educator helps them understand this web of life and explore the perceptions that tell us how to navigate it.

References

- Camazine, S., Deneubourg, J., Franks, N.R., Sneyd, J., Theraulaz, G., & Bonabeau, E. (2001). *Self-organization in biological systems*. Princeton, NJ: Princeton University Press.
- Capra, F. (1996). *The web of life: A new scientific understanding of living systems*. New York: Anchor Books.
- Churchland, P.S. (2002). *Brain-wise: Studies in neurophilosophy*. Cambridge, MA: MIT Press.
- Davis, B. & Phelps, R. (2005). Exploring the common spaces of education and complexity: Transphenomenality, transdisciplinarity, and interdiscursivity. *Complicity: An International Journal of Complexity and Education*, 2(1), pp.1-4.
- Davis, B. & Sumara, D. (2006). *Complexity and education: Inquiries into learning, teaching, and research*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Doll, W. C., Fleener, M.J., Trueit, D., & St. Julien, J. (2005). *Chaos, complexity, curriculum, and culture*. New York: Peter Lang.
- Elias, J.L. & Merriam, S.B. (2005). *Philosophical foundations of adult education* (3rd ed.). Malabar, FL: Krieger.
- English, L., Fenwick, T. & Parsons, J. (2003). *Spirituality of adult education and training*. Malabar, FL: Krieger.
- Kauffman, S.A. (1993). *Origins of order: Self-organization and selection in evolution*. New York: Oxford University Press.
- Kuklick, B. (2001). *A history of philosophy in America: 1720 – 2000*. Oxford: Clarendon Press.
- Longino, H. (2005). Can there be a feminist science? *Kontext*, 1,(2), 1 – 11.
- Palmer, P. (2004). *A hidden wholeness: The journey toward an undivided life*. San Francisco: Jossey-Bass.
- Prigogine, I. & Stengers, I. (1984). *Order out of chaos*. New York: Bantam.
- Prigogine, I. (1996). *The end of certainty*. New York: The Free Press.
- Schroeder, M. (1991). *Fractals, chaos, power laws: Minutes from an infinite paradise*. New York: W.H. Freeman.
- Stanley, D. (2006). Comparative dynamics: Healthy collectivities and the pattern which connects. *Complicity: An International Journal of Complexity and Education*, 3(1), 73-82.

The remainder of references are available upon request.