Pattern Thinking, Systems Thinking, and Complex—Transferrable Learning in Education for Sustainability

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Prepared for the *Education Sustainability Infusion Project* of the Coconino County Sustainable Economic Development Initiative (SEDI)
(October, 2009)

This short paper provides an overview of how we might approach teaching, thinking, and learning within the context of education for sustainability. The discussion of this approach, below, will touch on (a) systems thinking, (b) pattern thinking, and (c) a model of how these approaches to thinking provide a way to teach and learn for complex understandings.

"Sustainability" itself alludes to a number of contexts including ecology, economics, politics, society, technology, among many others. In fact, we cannot talk about sustainability without including these contexts. Such an approach to thinking that includes the interactions and interrelationships among multiple and sometimes conflicting contexts is referred to as ***systems thinking***. The basic idea of systems thinking involves moving away from a reductionist approach to learning and thinking to an approach that constantly refers to the "whole" system as the fundamental point of reference. Table 1 lists the overall characteristics, foci, thinking process, and concerns involved in systems thinking. However, the major intent of such an approach to thinking focuses on trying to develop understandings of whole systems that account for the functioning of all parts, their interrelationships, and the contexts in which the systems occur.

Table 1. Summary of systems thinking.

OVERALL CHARACTERISTICS	
◆ Systems thinkers are ***Generalists***	
◆ Systems thinking has a distinctive ***Worldview*** & ***Paradigm***	
FOCI	**THINKING PROCESSES**
◆ ***Whole Systems***	◆ ***Non-linear thinking*** → looping, divergent and convergent
◆ ***Relationships*** → relationships between parts and processes	◆ ***Questioning*** → posing penetrating & discriminating quesitons
◆ ***Feedback loops & other non-linear processes*** of information flow involved in regulation & adaptation	◆ ***Polarizing*** → examining tensions, dilemmas, conflicting views and variables, & other oppositional binaries
◆ ***Transformation*** → change and transformation processes	◆ ***Modeling*** → developing and refining explanatory models, principles, laws, etc.
◆ ***Parts*** — all parts are important (but the sum of them is less than the whole)	◆ ***Evaluating*** → critical examination of assumptions, variables, qualities, states, etc.
◆ ***Relevance & usefulness*** → outcomes and results are not as important as relevance or usefulness	◆ ***Stochastic*** → random variation and processes are important to systems thinking
CONCERNS	
◆ ***"Difference"*** is critical to understanding	◆ ***Identity*** of systems (based on difference)
◆ System ***survival*** as a ***selection*** process	◆ ***Uncertainty*** is part of the nature of systems
◆ ***Multiple Perspectives*** → important for understanding	◆ ***Complexity*** of variables, processes, etc.
◆ ***Boundary problems*** → artificially create reductionist separations	◆ ***Stability*** → based on relationships, not on goals or end-products; it is not linear

NOTE: This table is compiled from Bateson (1979/2002); Checkland (1985); Daellenbachand & Petty (2000); Paucar & Pagano (2009); Roberts (1978); Ulrich (2003); Weinberg (1975/2001); and Werhane (2002).

Thinking and in-depth learning are cognitive systems that focus on wholes, relationships, and complex interconnections. The dimensions of systems thinking occur along three intersecting continuums that result in a kind of “systems thinking space” (see Figure 1). Such thinking can focus on inquiring into and understanding a variety of systems that are situated somewhere within the systems space delineated by the continuums (a) of simple to complex, (b) from single system to multiple, interacting systems, and (c) from contextually bounded to applied across contexts. For example, a bicycle is a simple, but multiple, interacting mechanical system. Typically, this is the extent of the study of such a system. However, a bicycle is nothing without a rider. So, now we add the biological and cognitive systems, including emotions, of the rider. This addition of the rider begins to move the object of study towards a more “complex” end of the continuum and further towards the “multiple, interacting systems” end, as well. In addition, the rider suggests a context of human use. However, depending upon how far we want to go with this, the contextual continuum can be expanded to examining how bicycles are used in various situations, such as those involved in recreation, competition, and transportation. These situational contexts can vary further in specific cultural contexts such as bicycle use in the United States, China, India, Kenya, and the United Kingdom. In each of these cultural contexts, the meaning and function of bicycles vary.

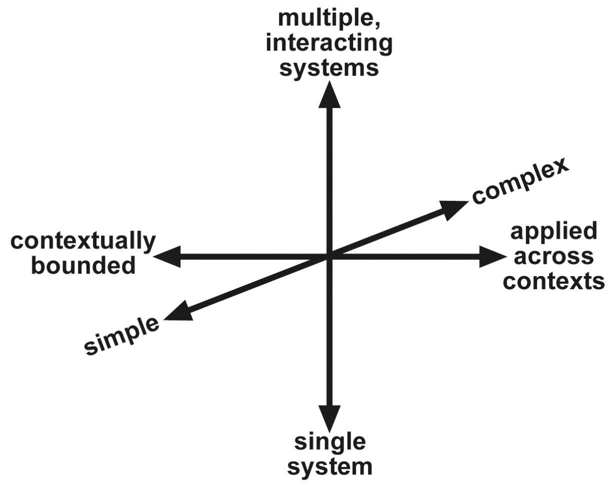

Figure 1. Intersecting dimensional continua of systems thinking.

Young children's thinking is characterized by the foci and processes of systems (Bloom, 1990, 1992), but the longer they stay in school, the less they continue to think in this way as the emphases change to linear approaches to remembering fragmented and disconnected content (Waldron, P. W., Collie, T. R., & Davies, C. M. W., 1999). However, previous attempts at teaching systems thinking to upper elementary school children has been shown to be effective in children's learning about social problems (Roberts, 1978), but such an approach to thinking has never been adopted in any comprehensive way in schools. If we are to pursue sustainability education, we need to move systems thinking to the forefront of our efforts.

Pattern thinking is at the core of all human thinking, in which the brain functions as a pattern recognizer (Anderson, J. R., Bothell, D., Byrne, M., Douglass, S., Lebiere, C., & Qin, Y., 2004; Weinberg, 1975/2001). However, even with this basic functionality, much of the way we approach thinking and learning does not take full advantage of our capabilities as pattern thinkers. Table 2 summarizes the overall characteristics, foci, thinking processes, and concerns involved in a more fully developed sense of pattern thinking. A fundamental operational view of pattern thinking involves a recursive approach to a loosely organized sequence of (a) recognizing patterns, (b) analyzing the functions and/or meanings of these patterns, (c) analyzing how these patterns are situated within one or more contexts, (d) finding these patterns in other contexts, and (e) using (applying, testing, analyzing, etc.) these patterns from one context in other contexts.

Although we have known that the brain functions as a pattern processor for some time, very little work has been done to develop this area in terms of learning. Beyond the early classic works of Weinberg (1975/2001) and Bateson (1979/2002), the only emphasis in this area has been in research on categorization (Varela, Thompson, & Rosch, 1991) and more recent work in a revision of schema theory (McVee, Dunsmore, & Gavelek, 2005). However, these research areas have not developed the idea of pattern thinking as an approach to learning. From the perspective of learning that focuses on patterns, we need to consider Gee's (1997) assertion that,

> Because the world is infinitely full of potentially meaningful patterns and sub-patterns in any domain, something must guide the learner in selecting patterns and sub-patterns to focus on. This something resides in the cultural models of the learner's sociocultural groups and the practices and settings in which they are rooted. Because the mind is a pattern recognizer and there are infinite ways to pattern features of the world… the mind is social (really, cultural) in the sense that sociocultural practices and settings guide the patterns in terms of which the learner thinks, acts, talks, values, and interacts. (p. 240)

From this perspective, Gee is pointing to the notion of transdisciplinary, meaningful patterns and to the mind as a pattern recognizer. Certainly, the embodied nature of patterns in our biological and cultural minds lends itself to pattern recognition as a basic function of the mind.

Table 2. Summary of pattern thinking.

OVERALL CHARACTERISTICS
◆ Pattern thinkers are ***Generalists***
◆ Pattern thinking contributes to a distinctive ***Worldview*** & ***Paradigm***
◆ Pattern thinking is ***Analytical*** & ***Aesthetic***
◆ Pattern thinking is ***Transcontextual*** & ***Transdisciplinary***
◆ Patterns are the material of ***Neuronal Function***

FOCI	**THINKING PROCESSES**
◆ ***Patterns*** -- repetitions of space, time, & mind	◆ ***Recognizing*** patterns (***cascading pattern extraction***)
◆ ***Relationships***	◆ ***Analyzing functions*** & ***meanings***
◆ ***Connections***	◆ ***Analyzing from multiple perspectives***
◆ ***Functions***	◆ ***Situating*** patterns ***in context***
◆ ***Meanings***	◆ ***Locating*** patterns ***in different contexts***
◆ ***Adaptation***	◆ ***Evaluating & testing***
◆ ***Complexity***	◆ ***Modeling***
◆ ***Recursiveness***	◆ ***Organizing***
◆ ***Models***	◆ ***Categorizing***
◆ ***Understandings***	◆ ***Associating*** -- analogs, metaphors, etc.
◆ ***Similarities*** & ***Differences***	◆ ***Thinking abductively***

CONCERNS	
w ***"Difference"*** is critical to pattern recognition & understanding	
◆ ***Assumptions***	◆ ***Systems***
◆ ***Transformative learning***	◆ ***Complexity***
◆ ***Context***	◆ ***Connects & Disconnects***

NOTE: This table is compiled from Bateson (1979/2002); Bloom (2004, 2006); Bloom & Volk (2007); Coward (1990); Hofstadter (1979); Lakoff & Johnson (1980); Thomas (1987); Volk & Bloom (2007); and Volk, Bloom, & Richards (2007).

The notion within pattern thinking that "tests" the applicability of functional patterns across contexts involves another frequently overlooked thinking process called ***abductive thinking***. In other words, abduction is a reasoning process that examines how certain ideas "fit" across contexts. Abduction occurs all of the time and is fundamental to the transfer of learning, but is not addressed in most of the transfer literature. Although abductive reasoning has been utilized in anthropology and served as a major mode of thinking for Gregory Bateson (1979/2002; 1991), it has not been addressed to any significant degree in the psychological literature.

A Model of Complex Learning and Thinking

This theoretical model of learning is based on a recursive approach for complex learning (see figure 1). Complex learning involves a kind of integration not typically utilized in classroom. Rather, this relevant and meaningful integration involves deeper conceptual connections, as well as a more "natural" process to investigating connections. By "natural," I mean a process that emerges from individuals and groups of students as they inquire into particular objects, events, and processes. In addition, such natural approaches lead to a kind of integration that has been referred to in a variety ways, including transdisciplinarity (Davis, 2005; Davis & Phelps, 2005; Lattuca, Voigt, & Fath, 2004), transphenomenality (Davis, 2005; Davis & Phelps, 2005), and transdiscursivity (Davis, 2005; Davis & Phelps, 2005). T*ranscontextuality* is another term that can be used in a way that subsumes transdisciplinarity, transphenomenality, and transdiscursivity. If we think in terms of transcontextuality, we include a variety of disciplinary contexts, as well as a other cultural, social, cognitive, situated activity, and experiential contexts, as well as the contexts of all phenomena and the contexts in which various discourse genres (see Bakhtin, 1986) occur. In addition, transcontextuality includes the creation of contexts, where new contexts emerge from specific interactions among people, objects, events, activities, and/or ideas (see "novel contextuality," as previously discussed). So, from the perspective of transcontextuality, integration involves recognizing and making connections to varying degrees of depth and abstraction across contexts.

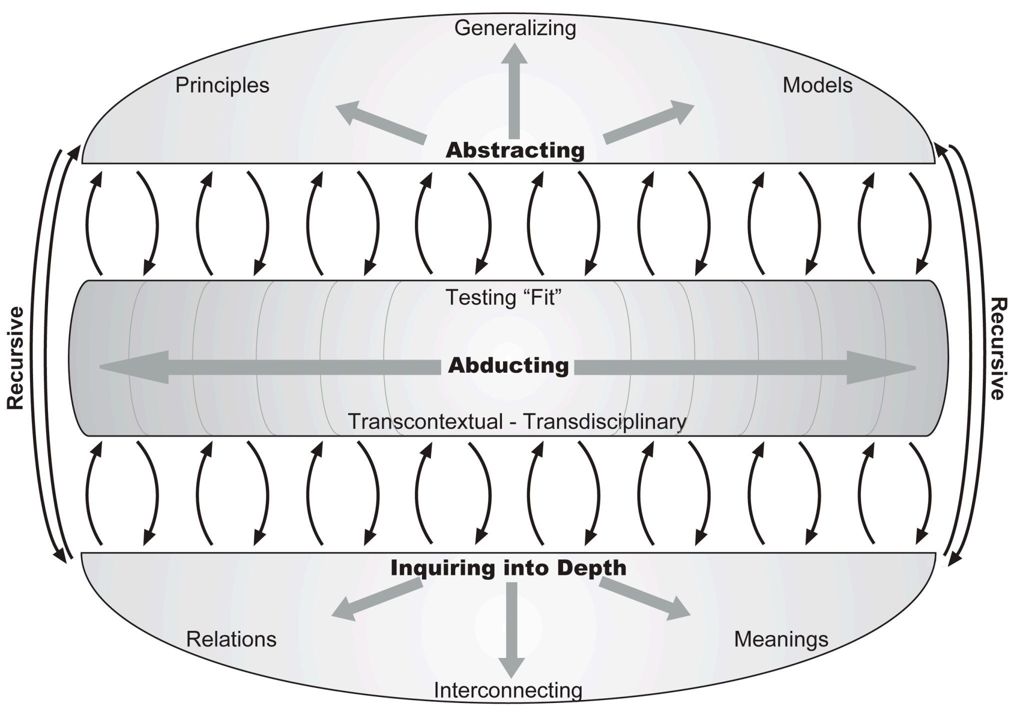

Figure 2. A model of complex learning and thinking.

The connections we make within and across contexts are fundamentally concerned with patterns of various sorts, which are those ideas or differences that make a difference. These connections are the basic "material" of which schemas are made. We name, classify, and create a variety of connections within and across patterns, which in turn can lead to a variety of creative insights and connections across schemas or contexts. Schemas are, in a sense, cognitive contexts, which undergo continual change as the result of individual and sociocultural meaning-making. In terms of complex learning, patterns that appear transcontextually are most useful in that such patterns carry common functional meanings, as well as context-specific variations of meanings, across contextual boundaries. A wide variety of conceptual patterns also can be addressed transcontextually, such as power, adaptation, force, and so forth. The general idea here is to recognize and construct relationships between patterns both within and across contexts. Pattern recognition is the beginning. The next step involves finding out how patterns interact or relate to one another in ways that create new patterns of function and meaning both within and across contexts. Such an approach to understanding patterns subsumes, and goes beyond, what is considered as analogical transfer. Analogical transfer looks for common and identical structures (or patterns) between the source and target domains (Caplan & Schooler, 1999). However, the approach suggested in this paper goes further. Common or identical structures or patterns are not necessarily required in that a pattern such as a binary may be a bilaterally symmetrical arrangement of sense organs in one context, but can be (a) technologically arranged headlights on a car in another context, (b) two people in a close relationship in another context, (c) magnet poles in a magnet, (d) oppositional factors that act as the central driving forces for cycles and systems, and (e) any of an infinite number of components in binary or greater relationships. Such occurrences of patterns are not identical or similar in the way that is intended in analogical transfer, but carry deeper and more profound similarities in function and meaning across contexts. However, any number of concepts and patterns can be utilized in a similar way. For example, the concept of power, which as very specific meanings in physics (i.e., the amount of work done in a period of time), also shares a sense of actions that have a particular impact across all contexts. So, "power" can be examined transcontextually in terms of personal relations, politics, mathematics, art, and so forth.

The model of complex learning, depicted in figure 2, is founded on these notions of transcontextuality and of the functional and meaningful connections and relationships of patterns as the material for learning. The fundamental processes involved in this model include an ongoing recursion through three basic reasoning processes (dimensions of the model):

a. ***Inquiry and analytical thinking*** that are involved in ***depth*** of understanding.

b. ***Constructive thinking*** involved in the development of ***abstractions***, which can be explanatory models.

c. ***Abductive and interconnective thinking*** as the means for ***transcontextual*** explanation building and complex learning, as well as for testing the "fit" of explanatory principles across contexts.

The recursions through each dimension provide for increasing depth of understanding of phenomena, for increasing scales of abstraction, and for increasing the extent or breadth of transcontextual connections and relationships.

Implications

An enacted version of this model should result in classrooms where students are actively engaged in explanation- and theory-building in ways that cross disciplinary boundaries and promote the type of learning essential to sustainability education. While such activities lead to more complex understandings, they also provide opportunities for individual students to draw on their particular interests and passions. Of course, teachers may have to read more widely and explore connections across disciplines. However, as a result, their work may become more of a dynamic process of helping students become producers of complex knowledge that is relevant to a wide range of interests. Teaching may move from repetitive routines to recursive explorations that result in new and exciting insights, which arise from the diversity and variation among students lived experiences. As in evolution, where variation lies at the heart of speciation, variation and diversity among students and teachers leads to new connections, ideas, and insights. Learning is no longer fragmented and decontextualized, but is connected not only within disciplines, but also across disciplines and throughout aspects of everyday life.

References

Anderson, J. R., Bothell, D., Byrne, M., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of mind. *Psychological Review, 111*(4), 1036—1060.

Bakhtin, M. M. (1986). *Speech genres and other late essays.* Austin, TX: University of Texas Press.

Bateson, G. (1979/2002). *Mind and nature: A necessary unity.* Cresskill, NJ: Hampton Press.

Bateson, G. (1991). *A sacred unity: Further steps to an ecology of mind.* New York: Cornelia & Michael Bessie Book/Harper Collins.

Bloom, J. W. (1990). Contexts of meaning: Young children's understanding of biological phenomena. *International Journal of Science Education, 12*(5), 549-561.

Bloom, J. W. (1992). The development of scientific knowledge in elementary school children: A context of meaning perspective. *Science Education, 76*(4), 399-413.

Bloom, J. W. (2004). Patterns that connect: Rethinking our approach to learning, teaching, and curriculum. *Curriculum and Teaching*, *19*(1), 5-26.

Bloom, J. W. (2006). *Creating a classroom community of young scientists (2nd ed.).* New York: Routledge.

Bloom, J. W., & Volk, T. (2007). The use of metapatterns for research into complex systems of teaching, learning, and schooling. Part II: Applications. *Complicity: An International Journal of Complexity and Education, 4*(1), 45—68 (Available at: http://www.complexityandeducation.ualberta.ca/COMPLICITY4/documents/Complicity_41e_Bloom_Volk.pdf).

Caplan, L. J. , & Schoooler, C. (1999). On the use of analogy in text-based memory and comprehension: Complexity of within-domain encoding and between-domain processing. *Journal of the Learning Sciences, 8*(1), 41—70.

Checkland, P. (1985). From optimizing to learning: A development of systems thinking for the 1990s. *Journal of the Operational Research Society, 36*(9), 757—767.

Coward, L. A. (1990). *Pattern thinking.* New York: Praeger.

Daellenbachand, H., & Petty, N. W. (2000). Using MENTOR to teach systems thinking and OR methodology to first-year students in New Zealand. *Journal of the Operational Research Society, 51*, 1359—1366.

Davis, B. (2005). *Complexity and education: Some vital simultaneities.* Proceedings of the 2005 Complexity Science and Educational Research Conference, November 20—22, Loranger, LA. (Available online at: http://www.complexityandeducation.ca).

Davis, B., & Phelps, R. (2005). Exploring the common spaces of education and complexity: transphenomenality, transdisciplinarity, and interdiscursivity. *Complicity: An International Journal of the Complexity and Education, 2*(1), 1—4.

Gee, J. P. (1997). Thinking, learning, and reading: The situated sociocultural mind. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 235-259). Mahwah, NJ: Lawrence Erlbaum.

Hofstadter, D. R. (1979). *Gödel, Escher, Bach: An eternal golden braid.* New York: Vintage Books.

in early education. Washington, DC: National Association for the Education of Young children (NAEYC).

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago: University of Chicago Press.

Lattuca, L. R., Voigt, L. J., & Fath, K. Q. (2004). Does interdisciplinarity promote learning? Theoretical support and researchable questions. *The Review of Higher Education, 28*(1), 23—48.

McVee, M. B., Dunsmore, K., & Gavelek, J. R. (2005). Schema theory revisited. *Review of Educational Research, 75*(4), 531—566.

Paucar-Cacere, A., & Pagano, R. (2009). Systems thinking and the use of systemic methodologies in knowledge management. *Systems Research and Behavioral Science, 26*, 343—355.

Roberts, N. (1978). Teaching dynamic feedback systems thinking: An elementary view. *Management Science, 24*(8), 836—843.

Thomas, D. W. (1987). Semiotics: The pattern which connects. *The American Journal of Semiotics, 5*(2), 291—302.

Ulrich, W. (2003). Beyond methodology choice: Critical systems thinking as critically systemic discourse. *Journal of the Operational Research Society, 54*, 325—342.

Varela, F., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience.* Cambridge, MA: MIT Press.

Volk, T., & Bloom, J. W. (2007). The use of metapatterns for research into complex systems of teaching, learning, and schooling. Part I: Metapatterns in nature and culture. *Complicity: An International Journal of Complexity and Education, 4*(1), 25—43 (Available at: http://www.complexityandeducation.ualberta.ca/COMPLICITY4/documents/Complicity_41d_Volk_Bloom.pdf).

Volk, T., Bloom, J. W., & Richards, J. (2007). Toward a science of metapatterns: Building upon Bateson's foundation. *Kybernetes*, *36*(7/8), 1070-1080.

Waldron, P. W., Collie, T. R., & Davies, C. M. W. (1999). *Telling stories about school: An invitation...* Upper Saddle River, NJ: Merrill/Prentice Hall.

Weinberg, G. M. (1975/2001). *An introduction to general systems thinking (Silver Anniversary Edition).* New York: Dorset House Publishing.

Werhane, P. H. (2002). Moral imagination and systems thinking. *Journal of Business Ethics, 38*, 33—42.