A Theoretical Model of Learning for Complexity: Depth, Extent, Abstraction, and Transfer of Learning

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Presented at the annual meeting of the American Educational Research Association, Chicago, April 11, 2007

> Yet we should oftener look over the tafferel of our craft, like curious passengers, and not make the voyage like stupid sailors picking oakum. The other side of the globe is but the home of our correspondent. Our voyaging is only great-circle sailing, and the doctors prescribe for diseases of the skin merely. One hastens to Southern Africa to chase the giraffe; but surely that is not the game he would be after. How long, pray, would a man hunt giraffes if he could? Snipes and woodcocks also may afford rare sport; but I trust it would be nobler game to shoot one's self. –
>
> "Direct your eye sight inward, and you'll find
> A thousand regions in your mind
> Yet undiscovered. Travel them, and be
> Expert in home-cosmography." (Thoreau, 1854/1995, p. 207)

Thoreau's musings on potentialities of human thinking could just as well be applied to the current status quo of schooling. We could substitute teachers for sailors, with teachers picking gum off the bottom of desks. (The intent here is not to blame teacher at all, but rather to comment on the institution of schooling that have made teachers into something short of professional quadriplegics.) The routines of teaching to the test or a standardized, teacher-proofed curriculum is not unlike "circle-sailing." At the same time, recommendations for increasing student achievement are like doctors treating symptoms, while the root causes rage on. The talk of schooling continues to focus upon the mile-wide, inch-deep curriculum in order to achieve high test scores that have little to do with actual learning. In the United States and to some extent in many other countries, the increasing emphasis on achievement has been leading to teaching strategies that decontextualize and fragment knowledge (Oliver, 1989). As a result, student learning tends to be limited to the memorization of facts that (a) are not connected to relevant and meaningful contexts, (b) are not, what we might call, thickly interconnected in rich conceptual frameworks, and (c) are not situated in relevant and meaningful cross-disciplinary or integrated contexts.

The fundamental concern of the approach being proposed in this paper is in how we can approach teaching in ways that provide opportunities for children to develop meaningful, relevant, and complex understandings that span subject matter disciplines. In describing a Teaching for Understanding project, Vito Perrone (1998) situated such a concern in the following statement:

> Renewed interest in teaching for understanding … is partly a reaction to the narrow skills-oriented curriculum that dominates schools as well as considerable evidence that large numbers of students are not receiving an education of power and consequence – one that allows them to be critical thinkers, problem posers, and problem solvers who are able to work through complexity, beyond the routine, and live productively in this rapidly changing world…. (pp. 13-14)

What is suggested in this statement is an approach to teaching that engages children in authentic learning tasks that are inherently reflective of the complexity of the world in which we live.

The intent of this paper is to present a theoretical model of teaching and learning that focuses on a recursive, triadic approach to learning for complexity, which, at the same time, should result in greater transferability of learning. The background frameworks for this model include examinations of current learning theory with special emphasis on the current state of

schema theory, a Batesonian perspective on epistemology as an active and reflective approach to knowing, and the nature and importance of patterns. Following a discussion of this background, the nature of transfer of learning is examined, along with a proposal for a revised framework for addressing and assessing transfer. At this point, we will examine the recursive teaching and learning model that is based on a triad of depth (i.e., analytical and deductive inquiry), abstraction (i.e., inductive and constructive approaches to explanation building), and extent (i.e., abductive and interconnective approaches to transcontextual understandings). The final section of the paper will discuss the implications for teaching and learning.

Learning, Concepts, Patterns, and Epistemology

Over the past several decades, mainstream conceptions of learning have moved from behaviorist terms to closely associated information processing models, then to models based on how people categorize, including schema theory. All of these models viewed learning and cognition in terms of the individual and limited by the boundaries of the individual brain. In recent years, work on schema theory went through a period of little development. Notions of situated and distributed cognition moved to the forefront of research during this time. The view of cognition moved from brain-bounded to views of mind as distributed throughout an individual's body and among the social context (McVee, Dunsmore, & Gavelek, 2005). These changes in the views of cognition have been stimulating researchers to rework their notions of schemas to account for these new perspectives of cognition.

McVee and others (2005) describe current work on schema theory as pursuing perspectives that see the mind as extending "beyond the skin" (p. 532), that hold the mind as discursively produced and distributed, and that the mind is a public and private bio-social-cultural process. Included in this new view are revised features of schemas:

- Have variables
- Can be embedded or nested within one another
- Represent knowledge at all levels of abstraction
- Represent knowledge rather than definitions
- Are active processes (not passive structures)
- Are recognition mechanisms whose processing is aimed at the evaluation of "goodness of fit" (p. 537) to the data being processed.

In contrast to previous notions of schema, the mind-body dualism underlying schema theory has given way to viewing schemas as transactional and embodied, where the knower and known mutually constitute one another. Such a view is "catching up" with what Gregory Bateson proposed in 1970. He described mind as a containing the entire feedback loop of information, so that for a man chopping down a tree mind includes the man's brain, his neuro-musculo-skeletal system, the axe, and the tree as information is transferred from brain to muscles to axe to tree to axe to muscles and back to the brain. Such a view served as the basis for Bateson's recursive epistemology, which emphasized the dynamics of how one comes to know, rather than the traditional sense of a static what-and-from-where-we-know epistemology (Bateson, 1970, 1979, 1991; Harries-Jones, 1995).

The implications of such a view of epistemology, include, in Bateson's (as cited in Harries-Jones, 1995) words,

> that epistemology is the great bridge between all branches of the world of experience – intellectual, emotional, observations, theoretical, verbal, and wordless. Knowledge, wisdom, art, religion, sport and science are bridged from the stance of epistemology. We stand off from all these disciplines to study them and yet stand at the center of each. (p. 9)

This interconnected view of knowing is not what is typically referred to in educational circles as subject matter integration, but is something much more fundamental. As I began my academic career, I began investigating children's idea about earthworms and other living things. As was typical of the influence of Bateson on my thinking, I was not thinking of Bateson at the time. As we analyzed the data from children's interviews, it quickly became apparent that the interconnectedness of children's thinking related to Bateson's epistemology. The results of this work were referred to as "contexts of meaning," where children's ideas drew upon multiple perspectives or sources, including various subject matter areas; their emotions, values, aesthetics; various interpretive frameworks; metaphors and analogies; personal experiences; imagery; humor; fantasy; and so forth (Bloom, 1990, 1992). For example, young children (grades 1 – 3) used a variety of statements to describe and make sense of earthworms, such as:

- "[worms] are both part reptile, part mammal, and part dinosaur, too"
- "[move like] slinkies"
- "[they're] playing"
- "their skin is like clothes for us"
- " [it looks like] a dragon's mouth"
- "I don't know about my worm body"
- "when something hurts us we curl up...they probably do that too when something hurts us we curl up...they probably do that too" (Bloom, 1990)

Statements like these relate to a variety of experiences and ways of thinking that cross contexts, work to provide a natural interconnected way of knowing, and provide rich "contexts of meaning." In these examples, children draw on prior school-type knowledge, personal experiences, imagination, and a kind of transactional embodiment (e.g., clothes, my worm body, and curling up). From this perspective, their schemas are integrative, cognitive, and embodied contexts of meaning. Such meaning involves what Varela, Thompson, and Rosch (1991) refer to as patterns of embodied experience and preconceptual structures. As such, these embodied schemas operate continuously in perception and activity.

This notion of patterns of embodied experience is fundamental to developing an understanding of meaningful learning and of learning that is transferable. This idea of embodiment is founded in the concept of metapatterns (Bateson, 1979; Volk, 1995), which are fundamental, overarching patterns or patterns of patterns. However, there is more to metapatterns than this, in that they are not just patterns, but are patterns that are evolved convergences. In other words, metapatterns are functional patterns that have emerged convergently through evolution. At the same time, these functional patterns have transferred to culture and manifest in cognition and technology (Volk & Bloom, in press). Ken Wilber (1996) takes patterns a step further in suggesting that all of reality is patterned, not just the biological, cultural, and technological. The most fundamental pattern, from his perspective, is a holon (a type of layering), which is a part and a whole simultaneously. In other words, holons are the building

blocks of everything. Volk suggests holons as wholes and clonons as parts, where clonons can be holons and holons can be clonons depending upon at what level of scale one is looking. As a result, such patterns are embodied at a most basic level in our biological and cultural beings, as well as in our physical worlds.

From this perspective, we need to consider Gee's (1997) assertion that,

> Because the world is infinitely full of potentially meaningful patterns and subpatterns in any domain, something must guide the learner in selecting patterns and subpatterns 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)

Essentially, 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.

As embodied and biologically-culturally-based functional patterns, these patterns have an inherent potential for meaning. I say "potential" here, because meaning, as Gee suggests above, is created from "something" we do. This "something," from the perspective of Gregory Bateson's (1979, 1991) work, involves seeing relationships in some context as the basis for creating meaning. McVee and others (2005), in referring to Gee (2004), discuss this notion of relationships in terms of how meaning exists within "relationships among and across experiences, actions, talk, people, and all sorts of culturally situated knowledge" (p. 547). However, such a view presents problems as discussed by McVee and other (2005):

> The great difficulty lies not in presenting students with more information but in providing for them a means to recognize and construct the relationships between various bits of information – that is, weaving the strands of information into a coherent schema that facilitates students' understandings of context. (p. 544)

From this perspective, we can begin to revise our view of schemas to one of schemas as cognitive contexts, which, at the same time, are the results of and basis for recursive relationship-making or the interweaving of thematic strands of information. From Bateson's (1979, 1991) perspective, such information is information of difference, of difference that makes a difference. Difference is not an object, a thing, but is based on relationship. Yet, while differences are not things, these differences or relationships are the substance of learning and the substance of the recursive pathways of pattern recognition and meaning-making. For example, figure 1 demonstrates a grade 5 boy's natural approach to patterns based upon difference. The task to which the boy was responding asked students to represent what life is all about on earth. When we examine this boy's representation, it is not a huge leap or inference to see how he focused on binary-based differences and recursively depicted a number of instances. In addition, the entire representation provides a peak at a sociocultural schema (or several overlapping schemas) of life, which provides a very sophisticated and critical perspective of human social and psychological contexts.

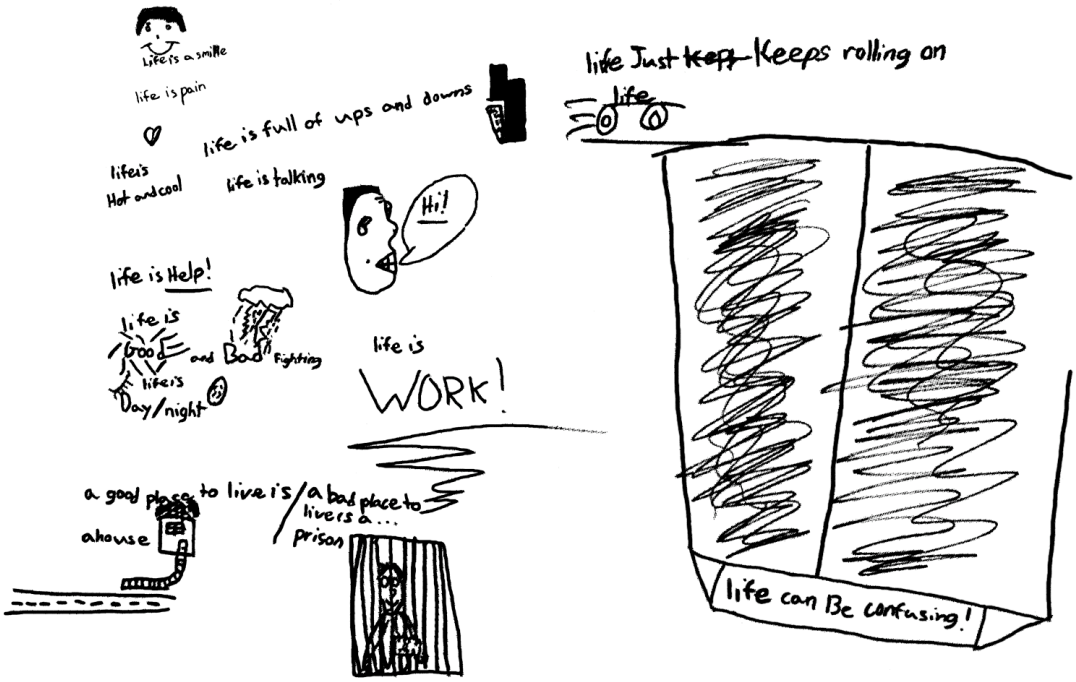

Figure 1. A grade 5 boy's representation of life on earth as a recursive examination of patterns (binaries) (Bloom, 2004a, p. 184).

In figure 1, the metapattern "binary" was the dominant thematic "glue." In addition to binary, Volk's (1995) metapatterns, include spheres, sheets, tubes, border and pores, layers (hierarchies, holarchies, holons, and clonons), centers, arrows, time and calendars, breaks, and cycles. Other potential binaries include clusters, rigidity-flexibility, gradients, emergence, webs, and triggers (Bloom, 2005b, 2005c; Volk & Bloom, In press). All of these metapatterns are functional in nature, but also are metaphoric and analogic, in terms of applying functions and meanings to a variety of contexts. So, when we talk about patterns and the human as a pattern recognizer, these and other potential metapatterns can be viewed as the fundamental ground, since they appear everywhere and are embedded in our very nature. However, any of a variety of patterns, such as power, force, adaptation, and so forth, can be applied across contexts and can serve as powerful tools for enriching meaningful schemas.

Transfer of Learning

For decades, researchers have been investigating the transfer of learning or knowledge, but until recently have only shown limited transfer (Haskell, 2001). Certainly, the question of what we mean by transfer is central to any discussion of this process. And, of course, there is little agreement among researchers about what the nature of transfer is and how it works (Lobato, 2006). In this section, I will provide a brief overview of the historical and current notions of transfer and provide a working framework to which the proposed theoretical model of complex teaching and learning can be applied.

The traditional notions of transfer focused on whether or not identical elements or representations transferred to different contexts. As summarized by Lobato (2006), more recent thinking suggests that there are a number of theoretical and technical problems with this traditional view of transfer:

1. The traditional approach to transfer research focused on experiments that manifested as some sort of "unnatural laboratory game." We should be looking at the natural processes people use to transfer knowledge. (from Lave, 1988).
2. Classic approaches to transfer were based on a functionalist view of knowledge, which stands in contrast to a situated view of knowledge that does not separate knowledge from practice. In addition, we could associate mechanistic and positivistic frameworks with this functionalist view.
3. The notion of context was very limited in the traditional view of transfer. Such notions of context only dealt with the context of the task at hand and did not take into account students' purposes and meanings. Certainly, the contention of Bransford, Brown, and Cocking (2000) that too much emphasis on context hinders transfer is based on this classical view of the context of transfer, rather than one that sees context from a broader perspective of meaning, purpose, situatedness, and so forth.
4. The "applying notion metaphor" (Lobato, 2006, p. 234) of classical transfer suggests that knowledge can be separated from activity, social interactions, culture, history, and other contexts.
5. The nature of the traditional view of transfer was static and suggested a separation of environment and process. The transportation metaphor is flawed for just this reason.

More recent alternative approaches to transfer address one or more of these problems. These approaches include (a) Beach's (1999, 2003, as cited in Lobato, 2006) consequential transitions, (b) Greeno's (1997, as cited in Lobato, 2006) affordances and constraints, (c) Bransford and Schwartz's (1999, as cited in Lobato, 2006) preparation for future learning, (d) Lobato's (2003, as cited in Lobato, 2006) actor-oriented approach, and (e) several activity theory approaches, such as Engestöm's (2001; 2003, as cited in Lobato, 2006), which involves a critical theory approach to situated activity. While traditional views of transfer focused upon identical elements, these more recent views look at the active transfer of symbolic representations in situated contexts. In addition, these recent approaches have examined (a) longer term learning, as opposed to the traditional "one-shot" approach; (b) shared structural features, as well as common surface features (Novick, 1988, as cited in Lobato, 2006); and (c) beyond just independent and isolated problem-solving tests to the use of group assessments, where additional resources and information can be used (Lobato, 2006).

Certainly, these recent research and theoretical approaches to transfer have advanced the field considerably. However, there are still several issues that need to be addressed. Such issues include, (a) a more detailed and expansive understanding of context and (b) a reconceptualization of learning and understanding that expands current views to include the significance of patterns, in terms of their transcontextuality, and recent work in chaotic and complex cognition. In addition, most recent views of transfer still emphasize two basic modes of thinking: deduction and induction. Abduction, which may occur naturally, 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; 1991), it has not been addressed to any significant degree in the psychological literature, with the exception of semiotics as introduced by Peirce (Stanford Encyclopedia of Philosophy, 2001/2006). Abduction is a reasoning process that examines how certain ideas "fit" across contexts. In considering that abduction needs to be taken into account, Thagard and Shelley (1997) have described a number of characteristics and results of abductive thinking that have a direct bearing on any discussion of transfer. When considering the construction of explanations as a major, recent emphasis in education (NRC, 1996), explanation may involve deduction and induction at some point in the process, but from Thagard and Shelley's perspective explanation itself is not deduction, but primarily an abductive process. At the same time, hypotheses and explanations are layered (either hierarchically or holarchically). In order to reason about hypotheses as layered ideas, abductive reasoning is required. In addition, the abductive process can lead to creativity and the development of revolutionary hypotheses, which is not possible through merely deductive or inductive reasoning. Another characteristic of abduction, according to Thagard and Shelley, is that completeness is illusive. Further potentialities for developing relationships across contexts are always present. Another aspect of abduction involves the notion of simplification in that as ideas are addressed across contexts there is a process of simplification. However, Thagard and Shelley maintain that such simplification is a complex process. Their final characteristic of abduction is that the process may be visual and non-sentential or verbal in nature.

Bateson (1979) considered abduction as a process of double or multiple description through the "lateral extension of abstract components of description" (pp. 157—158) as long as the same rules apply in both (or multiple) situations. From his perspective, the process of double description focused upon looking at the resemblances among differences, which, in his recursive vision, extended to seeing the resemblances of differences of resemblances of differences, and so on (Harries-Jones, 1995/2002). The notion of resemblances is fundamental to the Peircean and semiotics inferential process. Shank and Cunningham (1996) have described six basic types of abductive inferences, which are, (a) omen/hunch, which looks for possible resemblances from an initial observation; (b) symptom, which looks at whether an initial observation has properties of a case or larger phenomenon; (c) metaphor/analogy, which creates or discovers a rule from an initial resemblance; (d) clue, takes an initial observation as a clue to a more general phenomenon; (e) diagnosis/scenario, which creates a plausible scenario from a body of clues; and (f) explanation, which develops a plausible explanation or formal rule from a set of observations, clues, or resemblances. Essentially, this more detailed description of abductive reasoning focuses on developing some form of explanation from one or more specific observations of similarity to multiple instances either within or across contexts.

Another significant aspect of transfer involves the notion of abstraction. Traditionally, the process of abstraction has been considered an inductive and decontextualizing process (Lobato, 2006). However, more recent thinking conceives of abstraction from several alternative perspectives, which include the notions of (a) situated abstraction, where tools and meaning consist of artifacts and symbol systems; (b) abstraction in context, where prior constructions are vertically reorganized within the contexts of social practices; (c) collective and actor-oriented abstractions, where the notion of context moves from the traditional "experimental" context to the social contexts of classrooms; and (d) reflective abstraction, where abstraction is seen as a constructive process rather than one that is purely inductive (Lobato, et al., 2006). The common

threads among these alternative perspectives of abstraction involve seeing abstraction as a process tied to situations and contexts and as a constructive process.

The fundamental move of both schema theory and theories of knowledge transfer to include the theoretical perspective of situated cognition has resulted in a view of learning where context is seen as the situatedness of social practices. Although this move has had a remarkable and powerful effect on how we view learning and transfer, it still results in a limited view of context and what it may mean to transfer knowledge. Certainly, we are social beings and a vast majority, if not all, of what we learn is situated in our social contexts. However, we also spend considerable time putting personalized "spins" on and connections between the concepts and ideas we learn from a variety of social interactions. Such spins and connections can involve personal (and social) contexts of meaning (Bloom, 1990, 1992), subject matter domains as contexts, cultural and ethnic contexts, political contexts, physical and environmental contexts, and contexts of the imagination. In terms of transfer, these contexts can serve as the sources and targets of transfer.

According to Lobato (2006), current work defines three mechanisms of transfer: (a) Maxwell's (2004) *process causality*, which addresses the why and how of events and processes that are connected conceptually, including the use of focusing phenomena that link features of the learning environment to the way in which individuals generalize; (b) *social framing*, which takes a situated approach to transferring across contexts (i.e., intercontextuality); and (c) Marton and Pang's (2006) focus on the discernment of *differences* rather than similarity. The first two of these mechanism are primarily framed as situated cognition, while the third focus on differences can be applied in a variety of ways. While Marton and Pang's focus on differences is a major departure from previous work (i.e., a focus on similarities) on transfer, the notion of difference can be problematic. Marton's conception of difference is based on two levels: (a) "learning is a function of perceived differences (and similarities) in the learning situation… [and] (b) transfer is seen as a function of perceived differences (and similarities) in two or more situations and between those situations" (p. 512). Although these two levels of difference are important in reconceptualizing the nature of learning and transfer, they remain somewhat superficial when compared to Bateson's notion of difference and differences that make a difference.

As mentioned previously, "difference" was a foundational concept for Bateson's epistemology. From his perspective, news of difference is information and "… is the stuff of which minds are made" (Bateson, 1991, p. 162). In fact, his well-known phrase, "differences that make a difference," refers to significant differences that result in information. In addition, without difference and news of difference, there is no sensory perception, and such difference is not something material, not something localized (or situated), and not something that can be placed in time. He considered difference a psychological matter that is not in the outside world and is not solely in the inside world, but "is created by an act of comparison and this act is an event in time" (Harries-Jones, 1995/2002, p. 175). The core of his view of learning was based on difference, naming, and classification (Bateson, 1979). However, he was quite concerned with context, a discussed previously. His notion of context also was closely tied to the idea of difference. Essentially, context, from his view, is made of sets of transforms of differences (i.e., resulting information) at different levels of difference, so that "nothing means anything except in the presence of other things" (Bateson, 1991, p. 166). So, as Harries-Jones (1995/2002) summarizes Bateson's view that learning is a "form of mapping of variety and difference, incorporating a difference in contexts and levels of context" (p. 112). In addition, his contrast between difference and sameness has critical implications for the pattern-based model of

learning and transfer being proposed in this paper. A focus on sameness (or similarity) results in quantification, which was not an important outcome of thinking and learning for Bateson. On the other hand, a focus on difference results in recognizing patterns, which were critical to Bateson's epistemology, and which are critical to learning that is transferable.

Such a view of difference may include Marton's notion of difference as a subset, but has further implications. In a sense, all information are differences that make a difference, but what we should be interested in is a sense of teaching and learning that look for *Differences that make a Difference* (note capital Ds). In other words, we may want to consider emphasizing the big 'D' differences by looking at what makes up contexts and major underlying or overarching patterns. Such an approach does not just look at simple contrasts, but at patterns as the transformations of news of differences or as information about relationships and how these patterns of function and meaning interact, interrelate, or appear in other contexts. For instance, if students are examining earthworms in the classroom, they may notice how the worms move in a coordinated cycle of muscular contractions (i.e., multiple perceptions of news of difference resulting in the recognition of a cyclical pattern). This news of difference occurs in the immediate context of the activity. As they ponder this cycle of movement, they may notice that such a pattern resembles the motion of human beings (i.e., another difference that makes a difference). This connection to human movement occurs within a different experiential context, but within the same context of the academic domain (i.e., biology). As an examination of cycles continues, students may find that cycles are recursive carriers of information (news of differences that make a difference) and that they function to perpetuate systems of some sort. From this point, students can begin to find resemblances among different cycles in different contexts, such as those in astronomy, physics, cultures, politics, and so forth.

To conclude this discussion of transfer, we will examine recent thinking on the degrees or levels of transfer and then pose some possibilities for how we can reconsider the degrees of transfer in terms of complexity and the previous discussion of contexts and patterns. In Lobato's (2006) summary of transfer, he described the levels of transfer as ranging from two to nine different categories, depending upon the particular theorist. Figure 2 provides a useful compilation of six levels of transfer, as depicted by Haskell (2001). Although the distinctions between Haskell's levels are not always very obvious, we see a range from what is considered basic levels of connections with prior knowledge as fundamental to all learning to what he describes as creative transfer, which includes the generation of new concepts. The confusion in his levels of transfer occurs in the middle two levels where context is discussed. The third level, context transfer, describes applying knowledge to slightly different contexts. The fourth level, near transfer, is characterized by applying knowledge to closely similar, but not identical, situations. Discriminating between these two levels is confusing. What is the difference between "context" and "situation?" At the same time, the notion of "applying knowledge" is rooted in more traditional notions of transfer, as discussed previously, and does take into account contexts from the perspective of situated cognition. Such confusion is compounded even further when we consider the earthworm example in the previous paragraph. In some cases, a specific connection between two sets of information or knowledge may fall within the same context in one sense and cross contexts in another sense (e.g., different experiential contexts, but the same academic contexts with earthworm movement cycles). In the same way, "situations" may fall within the same context or in different contexts, or in both (or more) simultaneously.

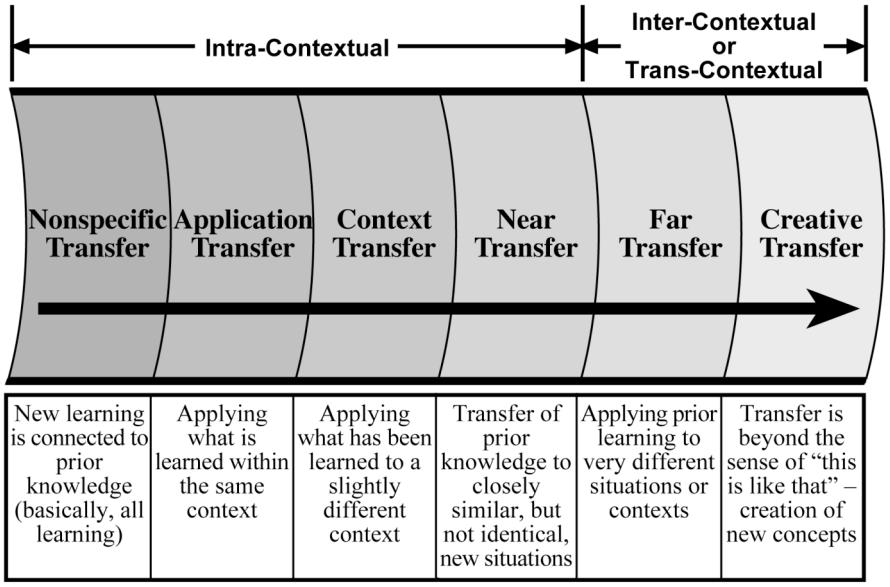

Figure 2. A graphic representation of Haskell's (2001, pp. 29-30) levels of transfer.

So, if we consider the basic framework of Haskell's (2006) in figure 2, but consider transfer in terms of context, an alternative framework of six degrees (or levels) can be depicted as connections within and across contexts as shown in figure 3. In this diagram, the six degrees of transfer include:

a. *Closely related transfer*, which is the equivalent of Haskell's nonspecific transfer in that it involves making connections to closely related or proximally located information (or differences that make a difference).

b. *Within context or domain transfer*, which involves connecting more distally related information within the same context.

c. *Within overlapping contexts or domains transfer*, which involves making connections to information that lies in overlapping or embedded contexts. It is important to note here that such transfer makes explicit connections to multiple contexts, as opposed to connections that make no reference to multiple contexts.

d. *Transcontextual or transdisciplinary transfer*, which involves making connections to a very different context without obvious connections to the initial context.

e. *Multiple Transcontextual or transdisciplinary transfer*, which involves making connections across multiple different contexts without obvious connections to the initial context.

f. *Novel contextual transfer*, which is related to Haskell's creative transfer where novel concepts and/or contextual situations are constructed.

These six degrees of transfer are specifically related to transfer distance and contextual situatedness, and hopefully provide a more distinctive framework for assessing transfer.

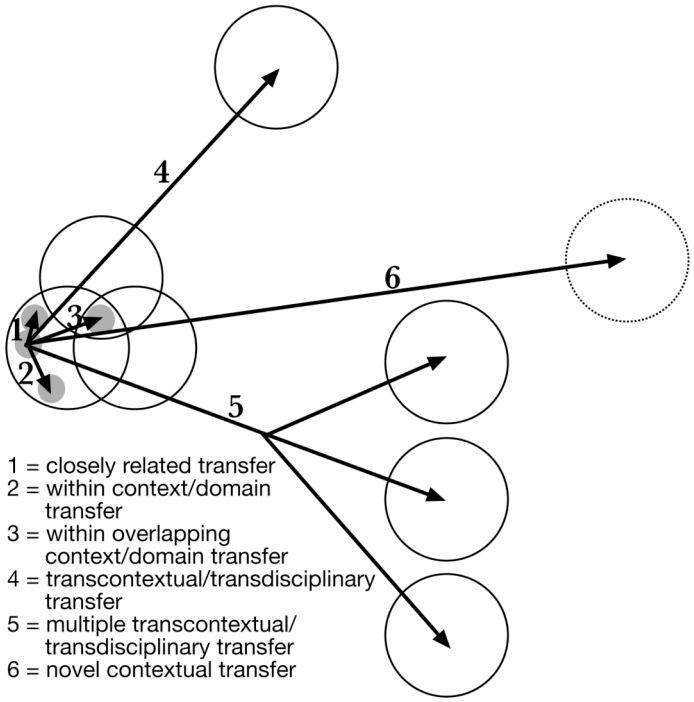

Figure 3. Contextual transfer model.

A more detailed examination of the contextual transfer model is shown in figure 4. In this figure two additional dimensions that need to be addressed when considering transfer. One dimension involves levels of cognition (Bloom, 2004a, 2005a), which include (a) initial emotional, valuative, and aesthetic reactions; (b) recognition; (c) comprehension (at the levels of words and meanings); (d) analysis (at the levels of relations and assumptions); (e) abstraction; and (f) transformation of beliefs, views, and conceptualizations. Although we may use a variety of typologies or hierarchies of cognition, the point here is that the thinking involved in learning and the transfer of learning occurs at different levels, which, for lack of a better term, may be considered as depth of processing. The other dimension to consider involves the substance of transfer. Again, a variety of typologies can be used here, but, for the present argument, the model in figure 4 includes, (a) patterns, (b) functions, (c) meanings, (d) interconnections and interrelationships, (e) insight, and (f) creativity. An alternative typology of substance is depicted in figure 5. This typology, created by Welzel (1998), was specifically geared towards increasingly complex levels of conceptual learning in physics. However, whichever typologies of cognition and substance of learning we choose to use, when we look at the intersections of these three dimensions (i.e., transfer distance or levels, levels of cognition, and substance of transfer), we can begin to delineate a complex matrix of possibilities for transfer. Such possibilities range from seeing proximal similarities in the way we react to specific patterns, events, or actions among closely related, intracontextual situations to creative constructions in novel contexts that have the potential to transform the way we understand "some thing."

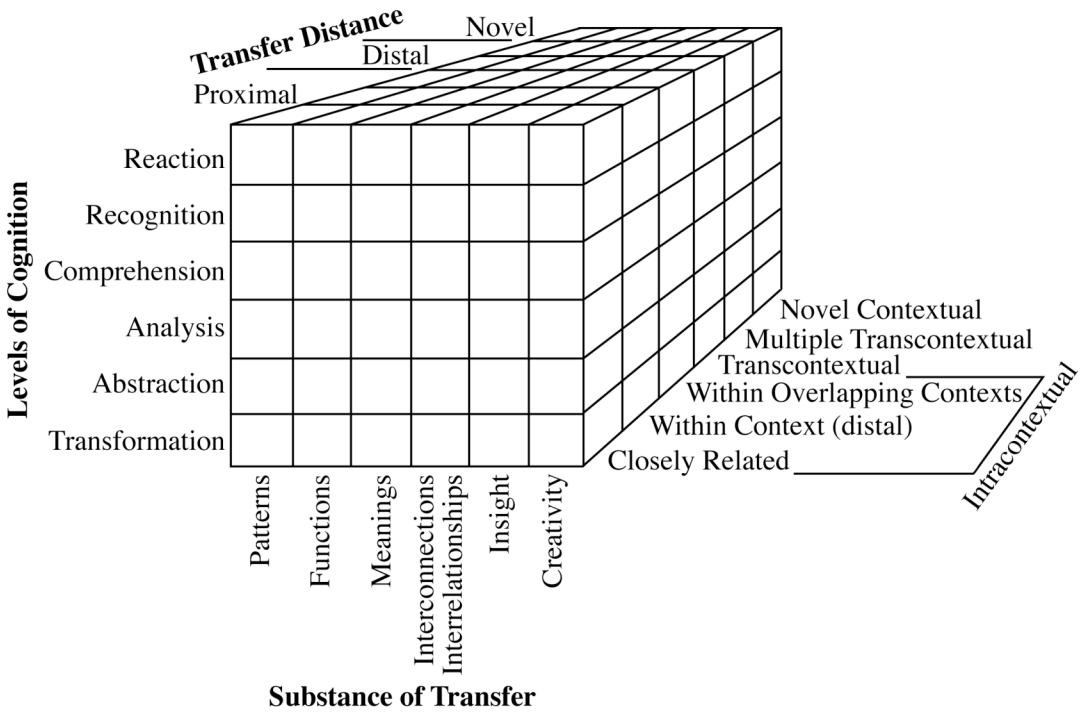

Figure 4. A grid depicting the interrelations involved in transfer: levels of cognition, the substantive material of transfer, and the contextual distance of transfer.

LEVELS	*INVOLVES CONSTRUCTION OF:*
Systems	stable networks of variable principles
Networks	systematic variation of a principle according to other principles
Connections	links between several principles with teh same or different variable properties
Principles	stable co-variations of parirs of properties
Programs	systematic variation of a property according to other stable properties
Events	links between some stable properties of the same or different classes of objects
Properties	classes of objects on the basis of common or different aspects
Operations	systematic variation of objects according to their aspects
Aspects	links between objects and/or identification of specific features
Objects	stable figure-ground distinctions

Figure 5. Ten levels of increasingly complex understandings (Welzel, 1998, p. 1109).

A Recursive, Triadic Model of Learning for Transfer

The proposed theoretical model of learning for complexity is based on a recursive approach for complex learning. From this perspective, complex learning involves integration. However, this notion of integration is not what is commonly conceived of and practiced in most classroom

situations. The common approach to integration is one in which the teacher imposes connections and activities that may or may not have varying degrees of relevance and meaning to students. In addition, such connections and activities generally are more conceptually superficial or are merely technical in nature, such as integrating language arts by writing a science report. Complex, relevant, and meaningful integration involves not only deeper conceptual connections, but also 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. Such integration 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). As mentioned previously in this paper, *transcontextuality* 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.

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 (or metapatterns) carry common functional meanings, as well as context-specific variations of meanings, across contextual boundaries. In addition to metapatterns, a wide variety of conceptual patterns also can appear or can be applied 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, but 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.

The model of complex learning, depicted in figure 6, 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. ***Deductive and analytical thinking*** that are involved in ***depth*** of understanding of various phenomena.

b. ***Inductive and constructive thinking*** that are involved in the development of ***abstractions***, which can be in the form of explanatory models.

c. ***Abductive and interconnective thinking*** as the means for ***transcontextual*** explanation building and complex learning.

The recursions through each dimension provide for increasing depth of understanding of phenomena, for increasing abstractions, and for increasing the extent of transcontextual connections and relationships. At the same time, there is a recursion between the three dimensions, which elaborates and/or creates contextual understandings while increasing the complexity of transcontextual understandings. At the same time, transcontextual abstractions are developed in ways that act as explanatory principles or models for patterns that occur within and across contexts.

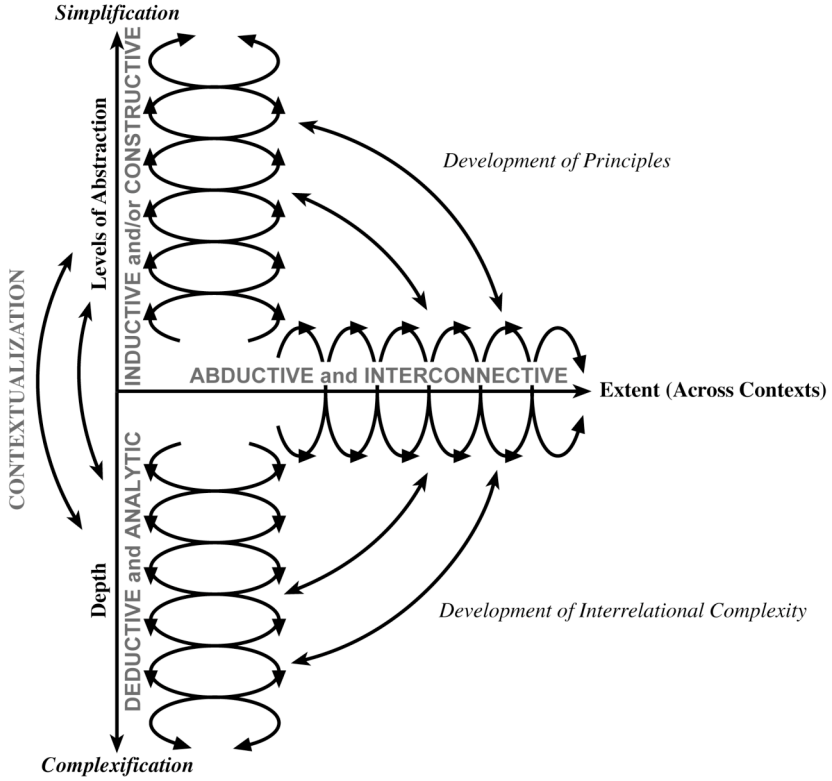

Figure 6. Recursive, triadic model of meaningful, relevant, complex, and transferable learning.

In essence, this model involves inquiring and learning as an exploration of layers: (a) layers of depth, (b) layers of abstraction, and (c) layers of contexts (transcontextual distances). Such a process of recursive layering is depicted in figure 7. Due to space limitations, this example

shows only a very brief outline of the possibilities of the type of content that can emerge from inquiries and explorations that represent depth, extent, and abstraction within an initial topic of the human circulatory system. Only two major patterns – binaries and cycles – are represented here. However, other fundamental patterns can be explored, including layering (e.g., cells as clonons; arteries, veins, and the heart as holons; arrows as directional flows; spheres, tubes, and sheets as heart, blood vessels, and cell membranes; borders and pores of cells and other transport sites; centers; time; breaks and branching; webs; and triggers). All of the additional patterns can be related to functions in other contexts, as well, and can lead to additional abstracted principles in models both within contexts and transcontextually. Such a recursive, triadic process results in learning that is complex, in terms of its interconnected contextual and transcontextual understandings, its depth of understandings involving fundamental and embodied functional patterns, and its abstracted functional explanations, models, and principles.

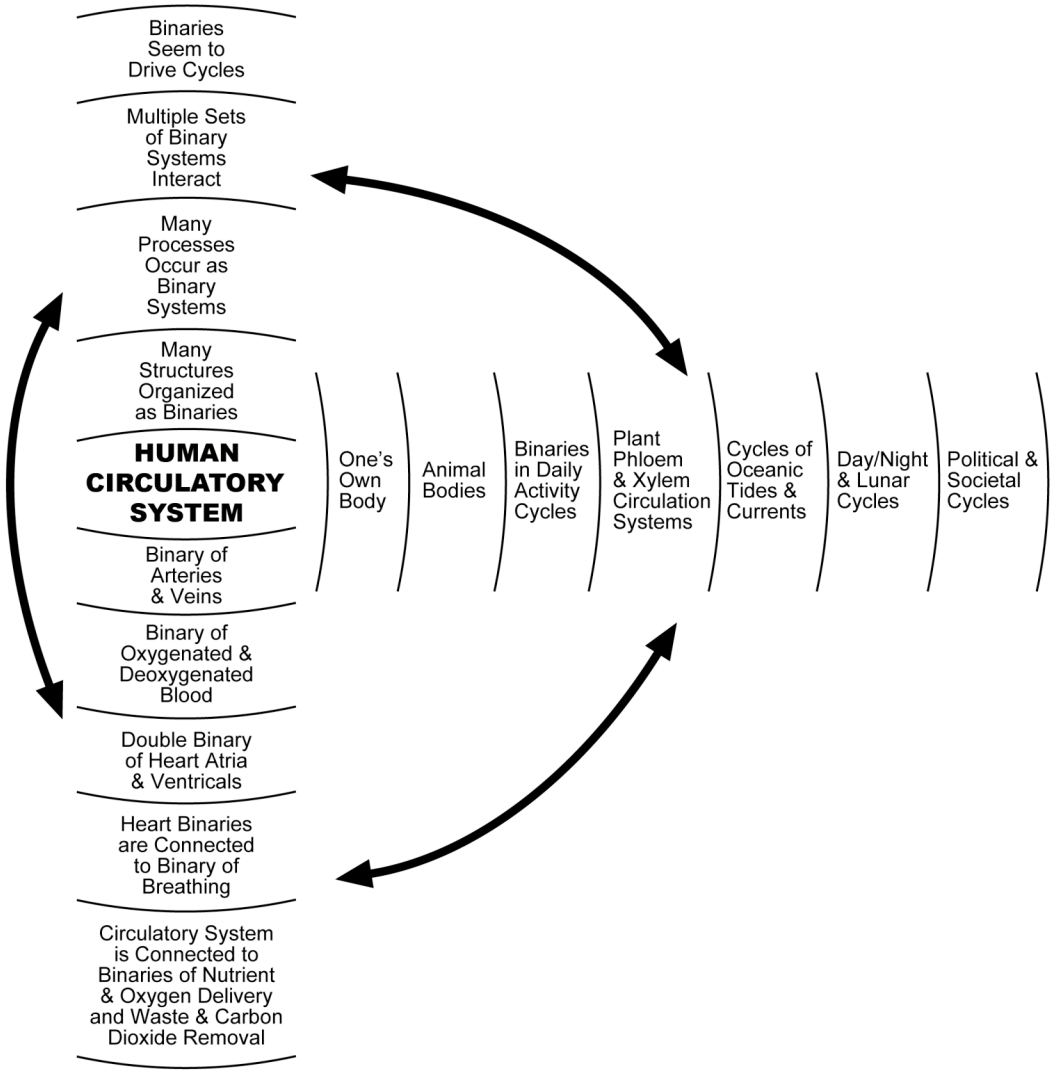

Figure 7. Simplified example of a recursive, triadic learning in layers.

In addition, the learning that results from such a model involves the understandings of multiple, interacting systems at a variety of scales. In other words, the cycle of oxygen and

carbon dioxide exchange is at a different scale than the cycle of oxygenated-deoxygenated, arterial-venal circulation. At the same time, both cycles are closely interrelated, yet the difference in scales provides a more complex understanding of both systems, which, in turn, can inform the other systems within the context of physiology, as well as inform other cyclical systems addressed through the abductive, transcontextual process.

Implications

As opposed to Thoreau's "circle sailing," which is not recursive and is much like Jayne Fleener's (2002) point that "repetition in schools is… like the cancer that grows out of control" (p. 170). The approach described here is helical. Mary Catherine Bateson's (1994) notion of learning as thematically helical depicts learning as a recursive process throughout time. Such an approach is descriptive of Thoreau's notion of exploring "a thousand regions in your mind… yet undiscovered" (Thoreau, 1854/1995, p. 207). In pursuing recursive paths to learning through analysis, abduction, and abstraction, we leave the door open to new insights emerging from students as they make their own connections among ideas across a vast array of contexts. Although we, as teachers, can make and offer our own connections, our primary task is to facilitate and orchestrate the process of making connections.

Much of schooling promotes disconnected knowledge, as well as other disconnections, such as those to oneself, to others, to learning, and to the environments and contexts in which we live. On the other hand, the recursive and triadic approach described in this paper provides possibilities to connect. The process of exploring the complexes of interconnections across contexts from those of our embodied selves to global contexts and contexts of the imagination provides students with opportunities to create understandings of themselves and the world of ideas. Such a process further provides opportunities to connect with oneself as a creator of knowledge and insight, as a human being in a world of many contexts, and as person with visions of possibilities and with the confidence to make sense of the world and to tackle the problems encountered along life's path. The social contexts of classrooms, in which such recursive exploration and learning occur, provide opportunities to connect with others as classmates share their recursive insights. At the same time, this approach focuses upon making connections to knowledge, to the entire learning process, and to a wide variety of contexts.

Another issue with disconnection and connection to learning involves the way we relate to and use various levels of thinking (see figure 4). In all too many cases, I see students at all levels react emotionally to an activity or a reading and then go no further. "It was boring." "I hated it." Such comments tend to disconnect and prevent further exploration. Even comments, such as "I loved it," can disconnect. We or our students react to something at an emotional level, but fail to pursue further connections. At the same time, such emotional reactions are critically important to connecting. Gregory Bateson (1979, 1991, personal communication, July, 1975) saw emotions as a critical component of developing deeper understandings. However, when we stop at the emotional reaction and not pursue deeper levels of thinking, such as, recognizing or seeing patterns and relationships, pursing understandings, analyzing relationships and assumptions, and developing abstractions, we fail to bring our emotional or aesthetic insights into a greater context of complex understanding. As an integrated process, from emotional reactions to abstractions, such thinking can lead to transformations in the way we see and connect with our worlds.

In addition to providing potentialities of connecting to our world and developing deeper, more extensive, and abstracted understandings, this approach not only presents opportunities for

the transfer of learning, but also models the entire process of transfer. Transfer is built into the entire model through recursive abduction and the recursive connections between analysis, abstraction, and abduction. This model addresses the entire range of transfer from closely related (intracontextual) transfer to novel contextual transfer (see figure 3). However, the one component not discussed thus far that needs to be incorporated into this model is a reflective component. The process of the model needs to be made explicit, so that students can see how their thinking through each of the three dimensions allows them to make connections and utilize their knowledge in a variety of ways. Such a reflective process is a major of a Batesonian epistemology that includes an understanding of how we think and learn. Students need to see the power of analyzing the complex interrelationships of functional and meaningful patterns, of abstracting basic principles and models, and of looking for connections across contexts from those closely related to their own personal experiences to a wide variety of sociocultural, academic, and imaginative contexts. In addition, the entire approach is one that addresses Doll's (2005) "S's": scientific, storied, spiritful, and spiritual. The scientific analyzes and abstracts while developing "stories" of explanation. Stories also are the processes and results of abducting and making connections across contexts. The spiritful and spiritual are embodied in the transformative potentialities of insight, connections, and wisdom. Essentially, the approach discussed in this paper is geared toward the pattern or *patterns which connect*, which was Gregory Bateson's (1979) life pursuit. Ultimately, such connecting patterns are metapatterns, patterns of patterns, that compose the contexts in which we live (Bloom, 2004b; Reynolds, 2005). They are the connections within and among ourselves and within and across our physical, psychological, and social experiences.

References

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

Bateson, G. (1970). Form, substance, and difference: The nineteenth annual Alfred Korzyloski memorial lecture. *General Semantic Bulletin, 37*, 5—13.

Bateson, G. (1979). *Mind and nature*. New York: Bantam Books.

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

Bateson, M. C. (1994). *Peripheral visions: Learning along the way*. New York: Harper Collins.

Beach, K. D. (1999). Consequential transitions: A sociocultural expedition beyond transfer in education. *Review of Research in Education. 24*, 101—140.

Beach, K. D. (2003). Consequential transitions: A developmental view of knowledge propagation through social organizations. In T. Tuomi-Gröhn & Y. Engeström (Eds.), *Between school and work: New perspectives on transfer and boundary-crossing* (pp. 39—62). Oxford, UK: Elsevier Science.

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. (2004a). *Creating a classroom community of young scientists (2nd ed.)*. New York: Routledge.

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

Bloom, J. W. (2005a). Levels of cognition. Retrieved March 23, 2007 from: http://elsci.coe.nau.edu/readarticle.php?article_id=18.

Bloom, J. W. (2005b). *Metapatterns – An Overview*. Available online at: http://elsci.coe.nau.edu/readarticle.php?article_id=22).

Bloom, J. W. (2005c). The application of chaos, complexity, and emergent (meta)patterns to research in teacher education. *Proceedings of the 2004 Complexity Science and Educational Research Conference* (pp. 155—191), Chaffey's Locks, Canada, Sep 30–Oct 3 (Available online at: http://www.complexityandeducation.ca).

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*, 61—100.

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.

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.

Doll, W. (2005). The culture of method. In W. E. Doll, M. J. Fleener, D. Trueit, and J. St. Julien (Eds.), *Chaos, complexity, curriculum, and culture: A conversation* (pp. 21—75). New York: Peter Lang.

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

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.

Gee, J. P. (2004). *Situated language and learning*. New York: Routledge.

Greeno, J. (1997). Response: On claims that answer the wrong questions. *Educational Researcher, 26*(1), 5—17.

Harries-Jones, P. (1995/2002). *Recursive visions: Ecological understanding and Gregory Bateson*. Toronto, Ontario: University of Toronto Press.

Haskell, R. E. (2001). *Transfer of learning: Cognition, instruction, and reasoning*. San Diego, CA: Academic 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.

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. New York: Cambridge University Press.

Lobato, J. (2003). How design experiments can inform a rethinking of transfer and vice versa. *Educational Researcher, 32*(1), 17—20.

Lobato, J. (2006). Alternative perspectives on the transfer of learning: History, issues, and challenges for future research. *Journal of the Learning Sciences, 15*(4), 431—449.

Marton, F., & Pang, M. F. (2006). On some necessary conditions of learning. *Journal of the Learning Sciences, 15*(2), 193—220.

Maxwell, J. (2004). Causal explanation, qualitative research, and scientific inquiry in education. *Educational Researcher, 33*(2), 3—11.

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

Novick, L. R. (1988). Analogical transfer, problem similarity, and expertise. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*(3), 510—520.

NRC. (1996). *The national science education standards*. Washington, DC: National Academy Press.

Oliver, D. W. (with Gershman, K. W.). (1989). *Education, modernity, and fractured meaning: Toward a process theory of teaching and learning*. Albany, NY: State University of New York Press.

Perrone, V. (1998). Why do we need a pedagogy of understanding? In M. Stone Wiske (Ed.), *Teaching for understanding: Linking research with practice*. San Francisco, CA: Jossey-Bass.

Reynolds, S. (2005). Patterns that connect: A recursive epistemology. In W. E. Doll, M. J. Fleener, D. Trueit, and J. St. Julien (Eds.), *Chaos, complexity, curriculum, and culture: A conversation* (pp. 263—276). New York: Peter Lang.

Shank, G., & Cunningham, D. J. (1996). Modeling the six modes of Peircean abduction for educational purposes. *Proceedings of Midwest Artificial Intelligence and Cognitive Science Conference*. Retrieved March 4, 2007, from http://www.cs.indiana.edu/event/maics96/Proceedings/shank.html.

Stanford Encyclopedia of Philosophy. (2001/2006). Charles Sanders Peirce. Retrieved March 26, 2007 from http://plato.stanford.edu/entries/peirce/#dia.

Thagard, P., & Shelley, C. (1997). Abductive reasoning: Logic, visual thinking, and coherence. In M.-L. Dalla Chiara, et al. (Eds.), *Logical and scientific methods*. Dordrecht, The Netherlands: Kluwer. Retrieved March 4, 2007, from University of Waterloo, http://cogsci.waterloo.ca/Articles/Pages/%7FAbductive.html.

Thoreau, H. D. (1854/1995). *Walden; or life in the woods*. New York: Dover.

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

Volk, T. (1995). *Metapatterns: Across space, time, and mind*. New York: Columbia University Press.

Volk, T, & Bloom, J. W. (In press). 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*.

Wilbur, K. (1996). *A brief history of everything*. Boston: Shambhala.

Welzel, M. (1998). The emergence of complex cognition during a unit on static electricity. *International Journal of Science Education, 20*(9), 1107—1118.