HOW NONLINEAR DYNAMIC SYSTEMS INFORM MEANING AND EARLY EDUCATION

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Abstract. This paper contends that educators need to prepare young learners to function with the predictable unpredictability of life in this century by participating in the kind of education that is transformational and adaptive to the ways in which children acquire meaning. When teachers implement a dynamic-themes theory of early education they can help children younger than nine years of age to integrate meaning. The isomorphic relationships apparent within each of several theories--script theory, Theory of Mind as metacognition, and chaos and complexity theory--together can provide evidence for the nature of meaning and its relationship to the nonlinear early education of children. The transformational-generative characteristics of these theories, that include constructed learning, inform dynamic early educational practice. Play, as one condition for meaningful early learning, also has particular significance in early education by affording an environment for assessing learning.
Key Words*:* Nonlinear dynamic systems, chaos and complexity theory, isomorphism, meaning, play, early education

HOW NONLINEAR DYNAMIC SYSTEMS INFORM MEANING AND EARLY LEARNING

This paper considers how an understanding of the nonlinear dynamic processes by which children younger than nine years of age construct meaning might influence the ways in which their educators might match instruction. There is abundant evidence that conceptual integration--the construction of meaning--is a nonlinear, dynamic system. Scholars are discovering that seemingly random nonlinear events follow a deeper, underlying pattern. Physicists, biologists, neuroscientists, psychologists, economists, anthropologists, linguists, and artists, among others at the frontiers of their fields, have studied nonlinear dynamic systems**. [Footnote 1]** They have studied turbulence, the moments when states of matter change. They are finding ways to measure *fractal* relationships, the rough edges of the world, as in broccoli and jagged shorelines (McDermott, 1983).

However, attempting to grasp the shared nonlinear processes that might bracket meaning is like trying to catch water in your hands. It might be easier to understand the *relationships* between the underlying forms and their surface representations if we were to capture snapshots of the nonlinear processes as in the examples that follow:

Underlying Forms	*Surface Variety*
A musical scale offers a limited number of notes…	but there are many ways in which the notes can be related to one another in their sequence or through different rhythms.
An underlying alphabet…	changes into different meanings as the letters are combined to create different words.
An underlying set of grammatical rules…	change into different meanings as words proceed in different orders.
Children use an underlying set of rules…	to represent a variety of emergent meanings during play. [grammar of play/script theory]
An underlying set of images in the physical	

world, such as cyclical change or synergy,… take unpredictable forms within physical or social environments. These forms share transformational relationships in which finite patterns can generate infinite possibilities. In these examples, the deep forms are predictable, and the surface forms are unpredictable. *It is within the transformation (phase transition/bifurcation) between the deep and surface forms that meaning can occur.* Neuroscientitsts contend that the neural networks of the human brain support these flexible and transformational processers (Payne & Kounios, 2008;Tognoli & Kelso, 2008)). For example, "T]he neural circuits must perform their functions locally, whereas the global distribution of activities is a collective function of the activities of the parts (Kohonen, 1989, p. 255)." It would follow that relevant pacing of activities would contribute to the efficacy of overall functions.

Isomorphism is a shorthand way to refer to the generative process by which these underlying *relationships* may take different surface forms. Analogies, built from cognitive connections based upon personal experiences, help humans infer the isomorphic connections. The connections reflect a "blending" between images (Fauconnier & Turner, 2002). Blending is a process about which human beings can be aware or unaware, in which there is a relationship between two or more images, whether real or imaginary. Blending is evident in such experiences as pretense, fantasy, humor, expectation, prediction, analogy, and problem solving. For example, "in the case of blending, at the moment of solution, the entire integration network is still active in the brain, even if unconsciously, while in the case-by-case analysis, at the moment of solution we have already lost most of the structure of the preceding steps (Ibid., p. 57)."

Young children manifest their capacity for such fluid connection-making as they engage in extensive syncretic thinking (Vygotsky, 1962; 1978), in which they extract properties and learn in personal ways. They directly and intuitively experience isomorphic relationships because their analogical thinking and isomorphic imagery is so powerful and fluid. Scholars, from their particular perspectives, lend additional support to the nonlinear dynamic nature of cognitive development as they discuss the interaction and confluence of genetic factors, environmental conditions, and epigenetic processing (Boom, 2004; van Geert, 2000; Molenaar & Raijmakers, 2000).

Education is the quest for helping students to integrate new meaning and cross the threshold from not knowing to knowing. On the one hand, merely memorizing discrete, rote information or practicing isolated skills are insufficient for the education of an informed, contributing twenty-first century citizen. On the other hand, astrophysicist Michio Kaku's (1997) projections of the future suggest that the world needs people who can do three important things: 1) envision more than one answer to a question--even a question designed to elicit a single correct answer; 2) take imaginary leaps and act on them; and 3) adapt to rapid change. Another scholar envisions a future need in society for "synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely" (Wilson, 1998, p.269).

When educators understand how young children integrate meaning, they have the opportunity to accept the challenge of supporting young children's capacity to experience isomorphic imagery as a sturdy process in connection-making and blending of concepts. In turn, the learners' comfort with isomorphic imagery also can help them adapt to emerging change. The sections that follow begin the process of envisioning the ineffable

nature of meaning and learning by considering redundant sources of indirect evidence from a confluence of parallel theories, a process of bracketing/indicating the tacit nature of meaning for purposes of influencing early education.

MEANING: INDIRECT ACCESS TO A DIRECT EXPERIENCE

When you understand something, you understand its meaning. Meaning is the center of human experience and the shared center of learning and play. It is an internal, personal experience. "[T]he construction of meaning requires many kinds of integration networks (Fauconnier & Turner, p. 122)." Meaning develops through the cognitive processes that underlie analogy and metaphor within the context of genetic and environmental circumstances. We use metaphor and analogy when we recognize part of a familiar image in a new encounter, thereby facilitating meaningful recognition and connections. "Metaphor involves the transformation of one thing seen as another…[and is]…unpredictable" (Belth, 1993, p.48). Metaphor is an internal cognitive process that becomes evident as children use language (Lakoff, & Johnson, 2003). Imagery and metaphor can contribute to meaningful thinking. The imagery in metaphor is dynamic and flexible (Prawat, 1999). Neuroscientists, using EEG (electroencephalogram) and fMRI (functional magnetic resonance imagery) technologies have credited self-organizing networks of neurons in receptive parts of the human brain with the associative aspects of thinking (Kohonen, 1989; Simonton, 1988). A "chance-configuration theory" holds that, within the context of sociocultural access and chemical conditions, "unstable mental aggregates [of neurons] must be sifted through before a stable permutation emerges (Simonton, 1988, p. 420)." Thus, the internal experience of meaning can result from the self-organized oscillations that take place within the brain's functions.

An individual child's self-concept and motivation can strengthen or limit the efficiency of ties between existing memories (event knowledge), to *integrate* a fresh connection (learning), or to *generate* a fresh connection (creativity). It is possible to observe young children's understanding and their use of imagery while they engage in sociodramatic play; in turn, young children also learn from one another within the play framework

More than just concepts or ideas alone, therefore, the acquisition of meaning also depends upon emotions and motives. Some meaning involves more powerful or weaker emotion. Self-concept and imagination also influence the oscillating strength of emotion. In the face of a challenge, self-concept and imagination could influence the particular way an individual dynamically gauges risk in relation to the chance for success. Thus, human beings selectively grasp specific meanings with different degrees of perceptual strength or motivation. Motivation is both an emotional and cognitive reaction to meaning, and it also influences how much attention we pay to particular experiences. Therefore, meaning is not "delivered". Rather, children construct meanings in unpredictable ways when they engage in focused interactions with others and the physical world.

Like music, it is a direct, personal experience. Figure 1, below, includes a representation of the mutually interactive, oscillating, forces that can influence the acquisition of meaning. It is worth noting that the psychological study of meaning in workplace organizations mirrors similar dynamics (Guastello, 2002). .

[Insert Figure 1 here.]

Educators who support young children's use of dynamic play and playful experiences can extend and enrich children's development of meaning. *Educators must therefore bridge the distance between adults' and children's knowledge in ways that children perceive as meaningful (Dewey, 1933).*

Although meaning is a direct, tacit, personal experience, it is possible to assess what two or more children engaged in pretense understand by observing their actions. Three theories—script theory, Theory of Mind as early metacognition, and chaos and complexity theory—can further clarify the acquisition of meaning and learning, and are presented in the sections that follow. The multiple perspectives of these theories bracket the transformational/generative processes that underlie conceptual learning. The juxtaposition of these different parallel, dynamic theoretical perspectives indicates/brackets the generally ineffable region of meaning that they address. The emergent characteristics within these processes further suggest a process by which educators can interact with young children, by specifically planning to expose the children to dynamic themes.

SCRIPT THEORY

Script theory (Nelson et al, 1986; Schank & Abelson, 1977) outlines the underlying 'grammar' of sociodramatic play. Children demonstrate their capacity to use the underlying sociodramatic play structures (script theory), a kind of 'play grammar of experience,' when they act out imaginary events with other children or an adult and represent their variety of experiences (event knowledge) in both predictable and emergent ways.

The cultural orientation to play contends that play functions in advance of development. One process, the Zone of Proximal Development, put forward by psychologist Lev Vygotsky (1987), suggests that play serves as a bridge between objects and thoughts. Children use objects and situations symbolically as a "pivot," for example, when a stick substitutes for a horse (Vygotsky, 1976). In a similar fashion, young children move into and out of the play frame (Bateson, 1979). The play framework facilitates an implicit choreography as one child enters into and "becomes" a role while another responds in a complementary role. Children continually clarify what is inside of the play frame and what is outside the play frame. Their engagement reflects their capacity to communicate about their communication (metacommunication) in advance of their years (Bateson, 1971, 1976, 1979). For example children step outside the play (metacommunication) to suggest, "You be the big brother and I'll be the baby," and then seamlessly step inside the play framework and behave in relation to the big brother (imagery). They demonstrate their capacity to classify what is and what is not play within this oscillating process. In these ways, the children subordinate themselves voluntarily and meaningfully to the "rules" (grammar/script) of the pretend play.

The more children play, the more they learn about the rules of engagement by interacting with others who provide models and feedback. In these ways, play leads development. You can see this taking place as the surface behavior of children's play becomes a vista through which to view their deeper understandings. An example of the transformational generative nature of script theory follows:

Child 1: "Wah! My leg is broken." Child 2: "Stop moving. I need to put on this bandage." A different Child 2 might have responded; "I've told you not to jump off the roof. Bad, bad. Now I have to get some splints." Yet a different Child,2 might have

responded, “Don’t move. I’m calling 911.” or another Child 2 might have commented, “Poor baby.” Thus, different children, or the same child at a different time, might respond in numerous ways to such a session of “Let’s pretend.”

Each response reflects a child’s event knowledge, his or her unique past experiences, and the influence of the other child. There is a strange attractor between the shared play theme and each child’s distinct past event knowledge that is apparent in each different child’s personal response. However, whatever the response, all the players implicitly agree that this collaborative, oral playwriting is relevant and meaningful to them. Thus, script theory involves the *relationship* between the underlying rules of play (metacommunication) and the variety of surface forms of imagery that children create together.

Children both use and expand their event knowledge as they develop oral scripts with others. The feedback that children receive during interactions with the physical world and others during play, and their other daily life experience, helps them to develop a metacognitive Theory of Mind, discussed below.

THEORY OF MIND

Interactions during play demonstrate that children between two- and four-years of age begin to develop an awareness of their own thinking and motives, and the thinking and motives of others, the kind of metacognition that psychologists have labeled [and capitalized], as a Theory of Mind. Psychologists have documented the ways in which young children’s Theory of Mind, defined particularly as metacognition, involves how they represent real and imaginary things, how they think about thinking, motives, beliefs, false beliefs, and deception (Astington, 1993; Astington & Pelletier, 1999; Bartsch & Wellman, 1995; Leslie, 1995; Leslie & Firth, 1988; Racine, 2004).

Researchers who have studied the development of metacognition have found that young children perceive a *transformational relationship* between self-awareness (metacognition) and awareness of others. Children represent the results of this shift of awareness, an implicit meaning, in explicit forms during sociodramatic play, making their Theory of Mind accessible to study. There is a parallel between the transformational processes involved in the children’s narrative play structures within sociodramatic scripts, and the processes in youngsters’ developing Theory of Mind (Ibid., Garvey, 1993; Harris, 2000; Harris & Kavanaugh, 1993; Perner, 1991

The act of pretend play entails an oscillation between negotiating “as-if” and crossing the threshold to pretending “if-then.” In effect, when children explore and play, they build images of how things work and what they might expect other children and adults to think and do. When children purposefully distort what they know to be true, for example, by denying that they pocketed another child’s keys; or telling their mother that they had not had ice cream after their father already had treated them to some ice cream, they reveal their power to understand the difference between truth and deception--an achievement of self-awareness as well as emotional induction (how their comments might affect another person).Moreover, the capacity of a typical four-year-old to tell a story ties in with the growth of the child’s Theory of Mind. An observable sequence begins with action sequences, reaction sequences, and then episodic narratives in which they set and attain goals (Benson, 1997).

Therefore, their Theory of Mind stands revealed as a system of relationships between underlying meanings/images and the many meaningful surface forms that

represent these images. In these ways, the child's Theory of Mind reveals the *relationship* between self-awareness (metacognition) and an awareness of the thoughts, beliefs, and motives of others. Another interpretation of this dynamic activity is the notion that "deblending" ("decompressing") cognitive integration ("blends") suggests that young children become able to "manipulate input spaces and projections independently (Fauconnier & Turner, 2002, p. 391)." The dynamic relationship, the oscillating movement between perceptions and the construction of meanings, that influence Theory of Mind mirrors chaos theory; in effect, underlying configurations may generate a variety of surface forms.

CHAOS AND COMPLEXITY THEORY: PHASE TRANSITIONS/BIFURCATIONS INTO MEANING

Many everyday experiences that we take for granted serve as the subject matter of chaos and complexity. Ccomplexity theory attempts to understand the 'predictable unpredictability' of everyday events. It is a body of theoretical work that focuses on the processes and relationships that unfold in the physical and social worlds. Complexity theory explores nonlinear, dynamic, seemingly random experiences and phenomena that, though different on the surface, manifest underlying regularities. Chaos theory considers the unpredictability of events.The weather, for example, may be generally predictable but specifically unpredictable. We might expect hot weather in the northern summer but are unlikely to be able to specify weather for a particular day. Consider also the nature of waves: At the seashore, they seem to break in unpredictable rhythms. However, a satellite photograph reveals considerable regularity in the long phase movements of distinct "scroll waves" (Briscoe, 1984; Sullivan, 1985).

We cannot always know when and how these regularities will take place. Indeed, we typically accept and live with them. In a similar way, children negotiate their play activities by moving in and out of the play frame in both predictable and unpredictable forms. When we have a broader view and greater distance in time or space, or look at many samples of children's interactions, we see deeper regularities more easily. In any case, the nonlinear aspects of life--such as emotions, aesthetics, and other directly experienced and immediate events--contribute to making being human interesting, puzzling, and significant.

Chaos and complexity theorists study systems that transform deep images into the variety of surface forms that represent these images. A few concepts from chaos and complexity theory may help to view everyday events differently, particularly children's nonlinear play in the context of linear teaching.

Sensitive Dependence on Initial Conditions (SDIC)

Definition. Most of us believe that if we put forth more effort, then we will accomplish more—and vice versa. In nonlinear terms, however, a small input may lead to a large output. SDIC refers to the "limited predictability" (Casti, 1994, p. 113) of the nonlinear relationship between initial events and their later manifestation. The examples that follow represent different nonlinear forms of reality and show how much more can happen when a seemingly small, initial event takes place.

Examples. Missing a school bus by a few seconds translates into being late to school by two hours, because there is no other bus for an hour or no more buses at all that day.

- A butterfly flapping its wings in one part of the world may influence a tornado in another part of the world (Lorenz, cited in Peitgen, 1990).Wind, temperature,

moisture, and the Earth's relation to the moon and sun are among the many forces that interact to influence and augment the initial movement of small, flapping wings. Therefore, there is a "stretch" between the initial conditions and the "chaotic" transformations that later transpire. (It might help to imagine this stretch in the same way that an analogy is a stretch between the referent and its comparison, for example, "She [referent] married a lemon [analogue].")

- A single choice may turn around a lifetime of possibilities. A young child who chooses to attend a sibling's violin lesson, for example, may develop a passion for music. A seemingly small humiliation or success early in life might mean the difference between benevolent or hostile expectations of others in adulthood.
- An educator who is highly directive and controlling may actually have less control over children's aggression when he is not present.

Relation to Play. When young children play effectively, they learn through observation and practice how to enter a play frame sensitively. For example, children have redirected the focus of others, even if temporarily. Thus, initial conditions in play are subject to change through the influence of other players. These initial conditions are neither predetermined nor random. Within the play framework the general *process* or oral script development is predictable, but the specific *product* is not.

The shared event knowledge of the players is an initial condition that might influence the direction and depth of the play. If players can adapt to each other's different knowledge backgrounds, then they are more likely to extend the play.

The predictability or grammatical structure of play constitutes a kind of 'attractor' in chaos theory. When weaker, the attractor (or underlying grammatical system) permits more random and unpredictable representations. Nevertheless, these representations still retain their relationship to the underlying attractor. Although play may have weak ties to reality, children's creativity becomes apparent in their fantasy play. They create connections by using analogies. The creative process functions best when there is greater stretch between the analog and the referent. Children's play and their grasp of meaning are therefore unpredictable. In a similar way, different children doing the same thing at the same time may have different experiences; the same children doing different things at different times may have equivalent experiences.

The variety of play themes and negotiated solutions in particular play episodes are unpredictable, although the underlying rules of the play and the scope of the oral scripts are generally predictable. *Children generate play scripts that depend upon the initial conditions of the play context and the player's experiences. The play evolves unpredictably within the predictability of the underlying enplotting (planning) –enacting (doing) rules of the play*.

Self-Organization of Systems

Definition. Another complexity theory concept, self-organization of systems, refers to the tendency of a gathering (for example, a mob; a cocktail party; elements of a weather system; ingredients in a recipe; leaves in a stream; atoms in a cloud chamber; molecules in gases, liquids, and solids), to evolve and develop a coherent process.

Examples. Tornados are self-organizing systems; shifting winds, or a small circular shake of liquid in a bottle, seem to organize in an increasingly coherent and turbulent way.

- The climate of each classroom is a self-organizing system. For example, when young children make reasonable choices among activities and can pace their participation, they tend to be more productive, autonomous, and responsible for their own self-direction when the teacher is absent.
- In a parallel way, when five- and six-year-olds enter a burst of spontaneous giggling, the giggling tends to spread and grow in a self-organized manner until the energy eventually dissipates. There appear to be 'predictably unpredictable' attractions between the mix of children and the classroom climate.
- Problem solving is another self-organizing process. Brain studies confirm that people do not solve social and complex problems one part at a time in a linear way. Rather, during problem solving, brain cells function in holistic, self-similar ways to create networks of connections.

Relation to Play. Youngsters organize and solve many problems that arise during play. They collaboratively plan their sociodramatic play scripts (a process of meta-communication when they talk to, signal, or prompt one another). They then play out the oral script using their individual imagery. The oral sociodramatic play scripts consist of conventions and rules that generate an infinite set of surface combinations. *The grammar of play is thus self-organizing*.

Educators who consider the self-organizing capacity of young children can adapt varied experiences for different children. They understand that different physical or social experiences can represent the same underlying dynamic theme, such as cyclical change. They can be secure in the knowledge that young children will induce the imagery.

Problem solving during sociodramatic play entails a combination of logic (meta-communication) and intuition (imagery). The networks of neurons in youngsters' brains organize the logic and intuition in self-similar patterns on different size scales as fractals, discussed further below.

Fractals

Definition. Like the networks of neurons in the brain, fractals describe self-similar patterns that appear on smaller to larger size scales. "The essential fractal nature is a self-referential or recursive function (Guastello, 1995, p. 30)." "Fractals are curves that are irregular all over. Moreover, they have exactly the same degree of irregularity at all scales of measurement" (Casti, 1994, p.232). Fractals also are apparent in mathematical representations of self-similar "sets" (Smith, 2007, p.76).

Examples. Fractals describe jagged perimeters such as rocky coastlines and broccoli. The different scales, whether smaller and larger, whether physical or mathematical, are self-similar.

- Another example of a self-similar relationship is that children feel more comfortable with mathematics and achieve more when they work with an educator who feels more comfortable with mathematics (Karp, 1988).

Relationship to Play. Children of different ages with different language skills who enter similar oral sociodramatic play scripts retain the underlying grammatical structure of the play frame. *As they develop as players, children retain the play grammar but play for longer periods of time with different degrees of thematic coherence and linguistic complexity*. Within this process, the pace of development may vary. In these ways, the degree of expanded development, a fractal image, follows a similar underlying grammar of play.

Children build meaning during the transitions between the self-similar system of rules and their representations; the transitions oscillate between meta-communication and imagery. Complexity theory considers these transitions of meaning.

Complexity Theory and Phase Transitions

Definition. Complexity theory proposes a process—in particular phase transitions—by which learning could take place. Phase transition refers to the "bridge" between one state and another, the transition system that includes the time before insight and the crossing over to meaning.

Pyschologists build upon Piaget's work on construction of learning and the accommodation to new meanings as follows: "[A]brupt qualitative changes in the equilibria of a nonlinear dynamic system as a result of smooth parameter changes are called bifurcation (in mathematics), phase transitions (in physics), or stage transitions (in biology and psychology). (Molenaar & Raijmakers, 2000, p. 44.)." The transition/accommodation reflects a bifurcation between one physical, social, or psychological system and another. The bifurcation develops within an oscillatory process. Within the context of creativity studies, neuroscientists credit the connection possibilities between unpredictable, but not necessarily random, permutations with the generation of fresh configurations. (Simonton, 1988).

Examples. Children watch the world around them carefully to capture the precise instant when changes occur, to know how far they need to move a magnet before it will no longer attract a clip, and to identify the exact spot to stand on a see-saw in order to tip it to the other side.

- A phase transition, like the fulcrum on the see-saw, is that turning point when one state changes into another, such as moving from up to down, turning from on to off; shifting from calm to turbulent; moving from in to out; changing from a liquid to a gas; transmuting from a milling group to a mob; defining a puzzle and finding its solution; being naïve and then knowledgeable; and so forth.

Effective educators try to create the active conditions for learning, **[Footnote 2]** that include play, within which phase transitions take place. Cognitive dissonance is another particularly fruitful strategy through which educators can create a basin of attraction. Cognitive dissonance is a three-part comparison between prediction/ expectation, experience, and comparison of the prediction with the experience. For example, young children often predict that a larger magnet would attract more paper clips than a smaller magnet or that a large piece of styrofoam is more likely to sink than a small washer. The relationship between the expectation and the findings generates a moment of surprise, a phase transition/bifurcation within which a new meaning may arise.

Relation to Play. Play features a dynamic phase transition between reality and pretense; metacommunication and representation; and enplotment and enactment. Phase transitions are areas of opportunity for adult or peer intervention; they are the moments during which meaningful, extended, and expanded (or constrained) development for children may take place.

Phase transitions serve as "attractors" that draw children to a change of focus. For example, when children identify or change a play theme or direction, they appear to grant a "warrant" that signals an agreement to proceed together (Cook-Gumperz, cited in Van Hoorn, Nourot, Scales, & Alward, 2006) "The boundary between two or more attractors

in a dynamical system serves as a threshold of a kind that seems to govern so many ordinary processes, from the breaking of materials to the making of decisions" (Gleick, 1987, p.233).

The phase transition process helps children to bridge non-meaning and meaning. Phase transitions also describe the process by which young children become aware of other people's meanings and move toward building a metacognitive Theory of Mind.

In addition, from a hermeneutic perspective, when the attractors of teaching and learning harmonize, children are likely to self-organize into other attractors (Nakkula, 1999). Educators who create timely phase transitions can support the development of meaning in the service of education. *The educator within this dynamic theoretical perspective can become a creator of sequential experiences that generate phase transitions from unfamiliar to familiar in ways that help children perceive connections and create patterns. Educators who work with young children and employ the conditions for learning to which children are receptive offer opportunities for playful experiences that include provisions for sociodramatic play.*

COMPLEXITY THEORY AND PHASE TRANSITIONS: VALUING PREDICTABLE UNPREDICTABILTIY IN EDUCATION

Learning, in these ways, takes place during phase transitions, the switching points between one state of being and another, ignorance and knowledge, or self-involvement and caring. Educators who understand the power of play in children's learning attempt to tip the oscillating balance between irrelevance and meaning, freedom and independence, and responsibility and impulsivity, by sensitively scaffolding (Vygotsky, 1962;1978) to create a bridge to increased complexity rather than controlling for its own sake**.** **[Footnote 3]** Chaos and complexity theory, along with script theory and Theory of Mind, confirms the generally predictable but specifically unpredictable nature of children's play and construction of meaning.

As children interact with the physical world and other people, they experience phase transitions that lead to fresh perceptions. Children perceive new meaning as first-time figures emerge from a background of familiar experiences. Their brains process these fluid experiences in fractal, holistic ways. Play, in turn, serves as a lymphatic system for the development of meaning through the holistic, integrative processes of the brain. The dynamic theory of play and meaning coincides with neuroscientists' current findings about the dynamic, holistic ways in which the human brain functions.

Neuroscientists have found that the human brain functions as a network of connections, particularly during problem-solving and learning. Rich experiences in the form of variety, feedback, and secure and supportive early encounters optimize brain functions in the service of emergent, self-organized learning. This perspective concurs with socially constructed theories of cognitive development (Molenaar & Raijmakers, 2000; van Geert, 2000).

Scholars who have studied the dynamics of the human brain agree on how educators might work with children (Bergen, 2002, 2003; Calvin, 1996; Jensen, 1998; Shore, 1997; Sylwester, 1995; Wolfe, 2001). The parts of the brain that children use during play are integrated mainly in the connections between the amygdala (predominantly emotional center) and neocortex (predominantly thinking center). The same sections of the brain also are involved with attention, potential attitudes toward learning, creative thinking, problem solving, and the arts. Strengthening the amygdala

strengthens these interrelated capacities. The term "emotional intelligence" (Goleman, 1995) has become a popular way to think about the significance of these connections.

Enriched experiences can increase and strengthen the connections between neurons, as if establishing increasingly sturdy paths along which connections may travel. Play is a powerful integrator of experience and can support the growth of connections. Richly varied experiences also provide opportunities for wholesome repetition and connection making to take place. Children have the chance to organize their own sequence of behaviors and integrate learning when teachers provide for play and playfulness in a conceptually-rich, experiential setting.

When children at play develop their own sequence of activities, they engage in creative behavior, "what Luria [a Russian [psychologist] called a kinetic melody" (Calvin, 1996, p. 100). "Kinetic" suggests movement and "melody" suggests connectedness; in effect, connected movement. This image is consistent with the perception of movement between the familiar and the new as a basis for learning to take place whereas a static or isolated fact may camouflage meaning.

Sudden movement, however, whether by a change of pace, direction, or emotional tone, can overshadow other meanings. For example, when humans feel stress or fear, the brain gives priority to coping with it. At such times, the connections in the brain are reduced to bolster survival. Under stress, the brain consumes its fuel, glucose, to cope rather than to learn (Jensen, 1998, pp. 19, 57). *Educators who support play and reduce children's stress can enhance children's problem-solving skills and learning*.

When children engage in play, their self-motivation, attention, and problem-solving intensify, and their stress level decreases. Natural body chemicals that foster a sense of well-being flow during such play. *Thus, the wholesome balance of play with work in early education can influence children's positive attitudes toward school*.

Therefore, considering the brain's neural processes--by which events shift, changes take place, and children make new connections—suggests that educators can help to optimize learning. Educators, then, can envision that the predictable in early learning is its predictable unpredictability. A dynamic theory of play and meaning celebrates ambiguity, predictable unpredictability, and the place of meaning as the core of early education. Within the dynamic processes of play and meaning, young children demonstrate their power as agents in their own learning.

Taken together, research findings (Fromberg, 1999, 2002) about the influence of play on learning and development along with nonlinear theories such as script theory; Theory of Mind; and chaos and complexity theory, conceptual blending theory (Fauconnier & Turner, 2002), chance-configurations theory (Simonton, 1988), and other neuroscience studies, provide a dynamic image of physical, social, and personal meaning. *The isomorphic images (patterns/models/themes) embedded in such nonlinear theories have greater generalizability than their multiple surface representations.* Educator intervention, through organizing direct experiences built upon underlying dynamic themes, offer opportunities for children to perceive meanings.

DYNAMIC THEMES: ISOMORPHIC IMAGES AS A GRAMMAR OF EXPERIENCE

Educators' intervention can grow out of interdisciplinary perspectives that share underlying dynamic themes, isomorphic images such as *cyclical change*, *synergy* (the

whole is more than the sum of its parts), *double bind* (incongruous appearance and reality), *dialectical processes* (conflict/contrast), and *indirect progress* (nonlinear movement*)* (Fromberg, 1995, 2002). These kinds of isomorphic images emerge in a variety of representations across different disciplines that children can perceive through direct experiences.

The editorial educational perspective in this paper grows out of the following context: experiences and concepts that reflect the study of the physical world and the social world deserve to be the center of early childhood curriculum in ways that support the real need for students to employ mathematics, the arts, and literacy (both oral and written) to represent their understanding. For example, the dynamic theme of *cyclical change* is apparent in such diverse phenomena as human, animal or plant history; population shifts; shadows; weather; evaporation of paint; the phases of the moon; and/or electric circuits. *Dialectical processes* are apparent in play with magnets, ramps, sharing scarce resources, human negotiations, and voting.

The isomorphism inherent in nonlinear transformational meaning suggests that dynamic themes can form the basis for a holistic theory of early education. In effect, different children at different times engaged in different activities might have equivalent experiences with a dynamic theme. Furthermore, exposure and receptivity to one kind of experience might predispose the learner to apprehend a different experience that represents the same underlying dynamic theme. In other terms, the dynamic theme as a conceptual integration network shares "an organizing frame for a mental space…[a] network…An organizing frame provides a topology for the space it organizes; that is, it provides a set of organizing relations among the elements in the space…Establishing a cross-space mapping between inputs becomes straightforward. (Fauconnier & Turner, p. 123)." Thus, the underlying forms, the dynamic themes, provide the opportunity for teachers to plan experiences across disciplines, within the sociocultural contexts in which children live, in order to facilitate opportunities for children to self-organize their connections between experiences.

Children experience isomorphic dynamic themes as they make their own connections. Their mental connections, the seat of meaning, typically are "incomplete and approximate" and transferable by analogy (Halford, 1993, p.23). Scholars from various disciplines have contributed to the notion of meaning **[Footnote 4]** "Meaning emerges from and only from isomorphism" (Hofstadter, 1985, p.445). Thus, the significance of content/meaning resides within the learner. A kind of grammar of experience, young children's perceptual/mental images reflect their capacity to distill connections that cross disciplinary domains. This transformational grammar of experience encompasses a holistic integration of socioemotional, psychomotor, cognitive, and aesthetic experience.

In Figure 2, the nonlinear transformational theories—script theory, Theory of Mind, and chaos and complexity theory that are represented within the three peripheral ovals, supported by brain research and the observations of children's play—provide an envisioned bracketing of the processes by which young children construct meaning. These theories support the weaving of a nonlinear dynamic model of teaching practice as represented in Figure 2. In turn, educators base the modification of experiences that reflect dynamic themes upon the study of everyday events and attempt to connect concepts that build upon the children's capacity for integrating meanings. The theories

and research on play together confirm an active image of the ways in which children both develop meaning and represent meaning through play. During young children's play, they have the opportunity to acquire event knowledge and a metacognitive Theory of Mind within the unpredictable flow of daily experiences. In turn, the dynamic relationships that define the theories depicted in Figure 2 suggest a way to perceive meaning when educators use dynamic themes as a basis for juxtaposing, sequencing, and pacing active experiences.

[Place Figure 2 here.]

As represented within the central oval of Figure 2, young children develop event knowledge and imagery within the core of everyday events situated in the context of particular cultural and political contexts at home, in the community, and at school—and by collaborating with one another during play. Children's fluid integration of dynamic themes flow in a recurring cycle within and around the core of everyday events.

Educators in turn observe and assess young children's behavior and can intervene sensitively in direct and indirect ways, and by providing resources. They thoughtfully plan, select, sequence, and cluster a variety of experiences from which children may perceive underlying dynamic themes. In these ways, educators create phase transitions/ bifurcations when they match relevant interventions with children's event knowledge. Such teachers also include and support time and space for the play framework to emerge. As children play, they oscillate between imagery and metacommunication, a 'breathing model' of how they learn to develop meanings, solve problems, engage in collaborative oral playwriting, and experience a sense of empowerment within the educational process.

The challenge for professional educators is to create happenings/basins of attraction with children that balance both planning and adaptation to emerging events. Educators can meet the challenge by welcoming more than one interpretation of an issue or solution to a problem.

Dynamic themes convey meaning in the multiple surface representations of a variety of physical, social, and representational experiences. *There is an isomorphic relationship between dynamic themes and the multiple forms in which children could experience them. That relationship parallels the transformational dynamics of script theory, Theory of Mind, and complexity theory.*

The use of dynamic themes that cut across separate subject areas unifies the isomorphic images that represent different disciplines. Educators who become comfortable with dynamic themes are able to serve the current and future need in society for deeper, creative understanding by flexibly matching teaching and learning. They develop alternative experiences and strategies to adapt to the variety of capacities of the youngsters. They also schedule and provision for play and playful experiences which empower children to construct meaning and skills that they will be able to use.

When deeper understandings take root, they cannot be blown away by a passing breeze. Roots transmit real nourishment. An educator who employs the nonlinear dynamic-themes approach provides conditions to stimulate phase transitions that create bridges between familiar and emerging meanings; keeps in balance order and wholesome chaos; control and freedom; and play and work. Phase transitions give children the potential to feel successful as they extend both their nonlinear and linear learning during exploration and play **[Footnote 5]**.

This century needs citizens who experience the power to think flexibly, collaborate effectively, and feel comfortable with predictably unpredictable events. Childhood play is the arena in which children can feel powerful and competent. If play is a lymphatic system of meaning, then a dynamic-themes education is the heartbeat that pumps challenges through that system, as children learn to construct new meaning.

FOOTNOTES

Footnote 1. *Nonlinear Dynamic Systems*. Carpendale & Muller, 2004; Fauconnier & Turner, 2002; Gleick, 1987; Guastello, 2002; Hofstadter, 1980; Holte, 1990; Kohonen, 1989; Kounios, et al., 2008); Levi-Strauss, 1949/1964,1969; Molenaar & Raijmakers, 2000; Rasmussen, 2008; Robertson & Combs, 1995; Sandkuhler & Bhattacharya, 2008; Sheth, B.R., Sandkuhler & Bhattacharya,.2009; Simonton, 1988; Smith, 2007; Van Geert, 2000; and Waldrop, 1992.

Footnote 2. *Conditions for Learning*. Play is one condition for learning along with the integration of inductive processes, cognitive dissonance, physical involvement, social interaction, opportunities for self-motivated revisiting, and underscored by a sense of competence (Fromberg, 2002, pp.9-10).

Footnote 3. *Scaffolding* is a term used by Lev Vygotsky (1978) to indicate the next-step of intervention that might help to create a fresh perspective.

Footnote 4 *Transformational Images*. Theorists have identified transformational images in various disciplines including interdisciplinary perspectives (Diamond, 2005; Kaku, 2008); linguistics (Chomsky, 1965,1972; Fauconnier & Turner, 2002); psychology (Jung, 1970); anthropology (Henry, 1973; Levi-Strauss, 1949/1969, 1964/1969); communications theory (McLuhan, 1963); computer technology (Minsky, 1967); game theory (Moore & Anderson, 1968); genetic research (Pfeiffer, 1962); and topology (Steiner, 1970). The idea of interdisciplinary confluences between art, music, and mathematics as "recursive loops" (Hofstadter, 1980, p. 445) is a compatible theory as are the general domains of chaos theory Gleick, 1987; Smith, 2007); and complexity theory (Waldrop, 1992). The use of "binary opposites" in a metaphoric approach to teaching through storytelling offers a similar "rhythm of expectation" (Egan, 1986, p.25; 1997).

Footnote 5. *Exploration* (also called functional play) takes place when an individual focuses on what something can do as compared with *play* when the focus is on what the individual can do (See Collard, 1979; Hutt, 1976; Wohlwill, 1984).

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Figure 1. The Nonlinear Dynamics of Meaning

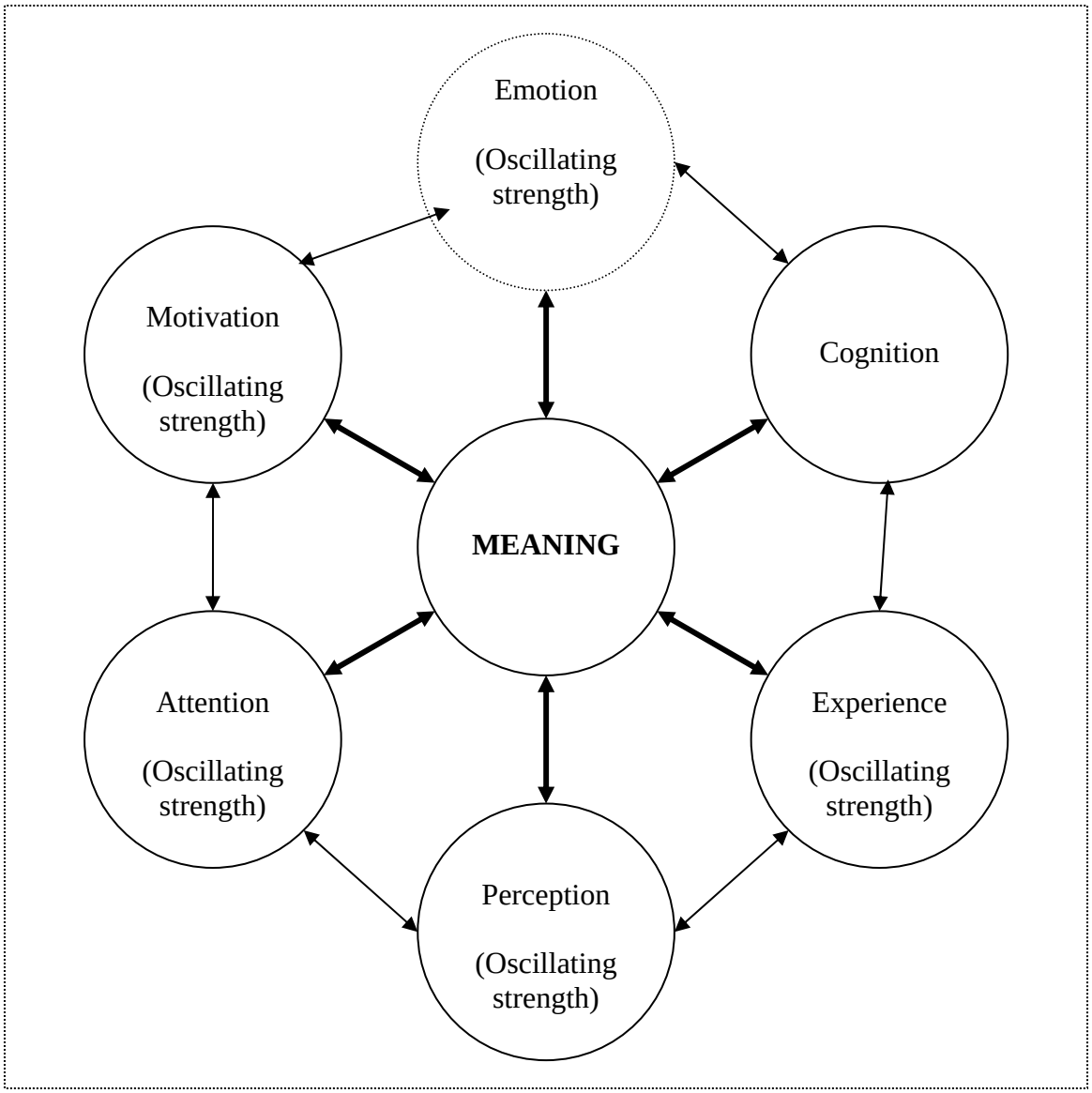
Emotion
(Oscillating strength)
Motivation
(Oscillating strength)
Cognition
MEANING
Attention
(Oscillating strength)
Experience
(Oscillating strength)
Perception
(Oscillating strength)

Figure 2. Nonlinear Dynamic Theories Weave a Nonlinear Dynamic Model of Teaching Practice


Script Theory
(Socio-dramatic Play and Narrative Structures)
Play Framework:
Relationships between
Meta-communications and imagery
The Child's
Core of Everyday Events:
The Child's Event Knowledge, Imagery, and Meanings
(Human Brain's Holistic, Fractal Processes)
(Cultural and Political Contexts)
Dynamic Themes
(Teacher's Contribution of Resources)
Integrating play among seven conditions for learning
Theory of Mind
Relationships between self-awareness
(metacognition) and awareness of
others
Chaos & Complexity
Theory
(Phase Transitions)
Relationships between predictably
unpredictable phenomena