Chapter 7
The Fractal Dynamics of Early Childhood Play Development and Nonlinear Teaching and Learning

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Introduction

How do children before 9 years of age actually learn about significant conceptual meanings, solve problems, and develop self-regulation? Educators who care to address this question—and are not content with rote memorization and children who parrot concrete verbalisms—can find some support in considering the dynamic, nonlinear processes by which young children learn. This chapter discusses the *relationship* between dynamic, nonlinear early learning and its implications for teaching. It makes sense to apprehend how young children learn in order to choreograph and coordinate how to teach in harmonious ways (that do no harm).[1]

Play. There is discussion in sections that follow of some current understandings of the dynamic, nonlinear ways that brains function as well as an explanation of the processes underlying young children's sociodramatic and construction play. Sociodramatic play typically involves two or more individuals who collaborate to improvise imaginative dramatizations that could be episodic. Construction play typically involves observable three-dimensional manipulation with materials such as blocks, clay, sand, and water.

Dynamic Themes Curriculum. The discussion can help to map the dynamic, nonlinear development of early learning that is meaningful to the players and relevant to the needs of today's world. There is also a description and discussion

[1] *To do no harm* suggests the sort of education that focuses on the adjustment of educators to the nonlinear dynamical ways in which young children develop and learn. Young children can experience harm when they feel rushed, pressured, or disrespected, and are expected to be passive and disempowered in educational settings.

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within sections that follow of a nonlinear, content-rich, and meaning-based system of the early educational dynamic themes curriculum. Dynamic themes curriculum is the transdisciplinary teaching-learning practice of the *grammar of experience* with isomorphic dynamic themes (see also Fromberg, 2002, 2012).

The Brain and the Future. Throughout these strands, there appear to be similar nonlinear dynamical systems functioning within children's brains as they play, develop, and learn. Brain dynamics, play dynamics, and curricular dynamics are relevant and timely perspectives. Scholars, for example, identify the twenty-first century's need for people who can be versatile, think flexibly, enact their imaginations, collaborate, be resilient, and feel comfortable with the predictably unpredictable future (Bergen, Davis, & Abbitt, in press; Kaku, 1997, 2008; Yelland, Lee, O'Rourke, & Harrison, 2008). Young players already demonstrate these characteristics in their play and imagination, an observable venue in which to launch the narrative.

Sociodramatic Play

Sociodramatic play and imagination is one among seven *integrated* conditions of learning in early childhood (see Box 7.1) that begins to reveal the nonlinear dynamics of development that include language development, spatial and visual progress, social competence, and connection-making skills. In particular, sociodramatic play that involves two or more individuals reflects a kind of *script grammar* that functions as a basin of attractors. In effect, children collaborate in a kind of oral playwriting that is both immediately unpredictable while the underlying script theory/grammar of play is predictable.

Box 7.1. Seven Integrated Conditions for Learning in Early Childhood

- *Play*. Children use their imaginations to find out what they can do and can develop executive function skills (Diamond, Barnett, Thomas, & Munro, 2007). They explore the relationship between reality and fantasy. [The oscillations between reality and imagination have the potential to cascade into phase transitions/bifurcations.]
- *Induction*. The relationships between familiar variables, as compared or contrasted with a fresh variable, assist perception whereas isolated facts or sounds might be camouflaged within a rote environment (see also Fauconnier & Turner, 2002). [The oscillations between familiar and fresh variables have the potential to cascade into phase transitions/bifurcations.]
- *Cognitive Dissonance*. The relationships between (1) an expectation, (2) a real experience, and (3) the surprise contrast between the expectation and

(continued)

Box 7.1 (continued)

the experience are an instance of new learning. [The oscillation between expectation and experience has the potential to cascade into phase transitions/bifurcations.]

- *Social Interaction*. The relationships and comparisons between personal experience and recognition of another person's possibly different perspective occur within the growth of a theory of mind and self-regulation. [Children also come to appreciate that others may have perceptions and ideas different from their own, thereby strengthening their theory of mind (Astington & Pelletier, 2005; Blair & Razza, 2007; Harris & Kavanaugh, 1993; Leslie, 1996: Perner, 1991)]. Theory of mind is important to written as well as oral communication because effective communication requires appreciating that other people have thoughts, feelings, and beliefs. [The phase transition that defines the *relationship* between a personally centered view and a de-centered view reflects a growth of meaning and *social comp*etence (Piaget et al., 1965).]
- *Physical Interaction*. Experiences that begin within three-dimensional phenomena enhance the relationship between past experience and a dissonant or new perspective, and support the development of symbolic representations. [The relationship affords opportunity for a phase transition.]
- *Revisiting*. The relationship between prior experiences and possible fresh connections and fractal developments with subsequent activities can exercise the brain's plasticity (Bowman, Donovan, & Burns, 2001; Gopnik, 2009; Sylwester, 2000). [The brain's fractal, integrative functioning strengthens connections.]
- *A Sense of Competence*. The relationship between a sense of success and risk involves the integration of the brain's emotional and cognitive capacities (see Bergen et al., in press; Damasio, 2003; Kaku, 2014). A sense of competence develops out of the paradox of *challenges* which offer both a manageable risk and a reasonable chance for success. [The balanced relationship between risk and challenge supports children's development of executive functions.]

Sensitive Dependence on Initial Conditions. Play is the incarnation of a *sensitive dependence on initial conditions*. Each player's prior experiences introduce particular event possibilities that influence the capacity of other players to respond in a variety of different ways. The play framework itself involves a dynamic, nonlinear *relationship* between meta-communication and personal imagery, and then group imagery. In effect, the *script grammar* of play typically proceeds as follows:

1. Enplotment meta-communication: Outside the play framework's thematic content, young players briefly begin to plan the topic or direction of imaginative play, e.g., You be the father and I'll be the child who fell.
2. Enactment of imagery: Immediately entering the play framework, players interact in unpredictable ways, e.g., One "father-player" might offer comfort and a bandage. A different father-player might call for a physician. Still a different father-player might scold the child for doing dangerous activities.
3. Unpredictable trajectories of play content within bounded parameters: The play generates unpredictable trajectories which might range between retaining and elaborating the episodic nature of the play script or generating other topical directions.
4. There might be a reiteration process of moving outside the play framework to refocus the play. The players might begin new emplotment and enactment or simply role-play physician-patient activity or hospital-themed play or drunken father play or decide to create a baby-parent interaction or superhero character play or have one or both children simply abandon the sociodramatic play area. They might alternatively invite another player-emplotment partner or subject matter into their play.

Phase Transitions. "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 predictable representations. Nevertheless, these representations still retain their relationship to the underlying attractor" (Fromberg, 2015, p. 425). Thus, phase transitions occur as the basins of attractors shift between meta-communication-emplotment and imagery-enactment. A particular action or comment by one player might serve as an attractor that leads to the self-organization of their play.

Phase transitions also occur when the episodic content oscillates or shifts unpredictably as each participating player contributes his or her enactment role. "The goal of the play, or the theme, serves as the attractor or driving point around which the play revolves and evolves. The dynamic nature of play implies that goals and themes can shift and, as they do, so will the attractor. These changes may be gradual or transformational, and then be governed by a periodic or even 'strange' attractor" (VanderVen, 2015, p. 415). Changes and transformations are related to periodic and strange attractors, respectively. Different children at different times are likely to have both shared and different experiences. Although the script components change, the play is identifiable as pretend play.

Relationships and Script Grammar. Relationships are important in sociodramatic play, beginning as early as the second year of life. A relationship takes place between the meta-communication in planning and the imagery within the development of the play script (Bateson, 1971, 1976, 1979). The *space between the relationships* defines the grammar of script theory. "Emergent behaviors … are all about living within boundaries defined by the rules, but also using that space to create something greater than the sum of its parts" (Davis & Samara, 2006, p. 148). The arc of the play emerges as the players interact to create fresh configurations.

Fractal Development. There is a *fractal progression* within sociodramatic play development. "Fractals describe self-similar patterns that appear on smaller to larger scales" (Fromberg, 2015, p. 426). Within the script framework, children learn from one another as well as from sensitive adult scaffolds. The fractal progression includes the (1) expanding development of language complexity and vocabulary; (2) increasing social competence; (3) increasing duration and coherence of thematic content; and (4) broadening event content knowledge. Each collaborative oscillating nonlinear progression incorporates a system of self-organization with a self-similar pattern at all scales/levels, far from equilibrium, and proceeds from simplicity and disorder toward complexity and order (Beran, Feng, Ghosh, & Kulik, 2014; Kurakin, 2011; Mandelbrot, 1983; see also Jadczyk, 2014). Thus, the fractal can serve as a heuristic for expanding memory, skills, and other developments through phase transitions. The fractal could also serve to predict patterns.

Oscillations Support Complexity Development. The oscillating movement between perception and collaborative construction of script development nourishes phase transitions toward increased complexity. The players' collaborative behavior creates a more complex drama than either of their individual contributions. At the same time, the underlying configurations of script grammar provide the organic medium, a basin of attraction, within which a variety of surface representations can emerge as bifurcations. The bifurcations result from phase transitions that grow out of the relationship between the shared imagery present in the players' metacommunication that, in turn, emerges as fresh imagery. The movement between enplotment and enactment involves the *relationships* and is essential for perception to occur. This process entails the unpredictability of events with the possibility of emergent bifurcation in new directions, an instance of chaos theory. For example, different children might each contribute a suggestion that might result in either a positive entrainment (synergy/the whole is more than the sum of its parts) or a destructive bifurcation. It may be the case that a fresh collaborative play configuration continues to develop and expand (synergy) or evolve into a schism that destroys the trajectory of the play so that the players disperse.

In these ways, sociodramatic play demonstrates that young children are capable of considerable self-direction and self-regulation. While play is a manifestation of children's imaginations, imagination is interdependent with thinking in concepts and reasoning (Vygotsky, 1987).

Construction Play

Construction play shares some of the play script grammar characteristics of sociodramatic play. However, young players often (1a) plan a structure, such as a three-dimensional construction with blocks; (1b) proceed silently to build; and (1c) only after the construction would they then engage in sociodramatic

interactions (Gardner, 2006). Block play, for example, continues to develop with (2) repetitive linear building in vertical or horizontal rows; (3) followed by connecting and bridging; (4) then deliberately placing blocks to create enclosures; (5) followed by forming patterns or symmetrical structures; (6) engaging in role playing, pretense, and prop substitutions; (7) culminating in realistic representation; and (8) sometimes fantastic representations (see Bullard, 2010; Clements & Sarama, 2009; Cross, Woods, & Schweingruber, 2009; Erikson, 1977; Hanline, Milton, & Phelps, 2001; Hirsch, 1996; Johnson, 1933; Moyer & von Haller Gilmer, 1956 citing Krotsch; Piaget & Inhelder, 1976; Provenzo & Brett, 1983; Reifel, 1984; Schwartz & Copeland, 2010; Wardle, 2003).

Fractal Development. A *fractal progression* occurs as children's three-dimensional constructions expand and extend from basic, underlying structural variables and possibilities to increasingly complex embellishments and creations. They strengthen the underlying visual and spatial skills that are necessary for understanding concepts in science, technology, design engineering, and mathematics (STEM). Building with blocks, manipulation of three-dimensional objects or liquids, and games with objects contribute to building these learnings. Children also extend their three-dimensional representations to two-dimensional representations, a pathway along the continuum of symbolic development. In these ways, children at play create physical as well as mental models of their world.

The Relationship Between Assessment and Educator Scaffolds

The observable and physical products of construction play and sociodramatic play provide both a concrete opportunity for educators to celebrate the progression of complexity and an opportunity to support further development. *Scaffolds* (Vygotsky, 1978) refer to sensitive educator interventions that can support development. A scaffold is the relationship between an educator's "(1) assessment of a child's learning potential in relation to (2) a learning pathway, and (3)[an] invitation and challenge that provide a relevant next-step experience" (Fromberg, 2012, p. 61).

Educator scaffolds might include verbal harmony, adapting to each specific situation, as follows:

- Simply describe what children are doing
- Ask what they have done or noticed
- Ask what problems they might have encountered and how they resolved them
- Ask what help they might want
- Wonder if they might use a particular prop or what else they might use
- Ask what labels/signs they might use
- Ask about their plans

- Wonder what might happen if . . .
- Wonder what a particular other child might contribute
- Enter the play framework with pretense
- Photograph/sketch the construction or interaction (see Ibid., pp. 62–66)

Scaffolds intend to keep opening children's capacities to experience phase transitions by focusing on the content of the play rather than judgments. For example, through sensitive scaffolding, an educator could introduce a new variable that children experience as a phase transition toward a fresh attractor; this process supports bifurcations by highlighting contrasts between variables or the *relationships* between expectations and actual experiences and possible next steps. Thus, *phase transitions help children to progress from non-meaning to meaning*. In this way teaching functions as an effective improvisational enterprise at its finest.

Brain Dynamics

"The brain is fundamentally a pattern forming self-organized system governed by potentially discoverable, nonlinear dynamical laws" (Kelso, p. 257). In particular, "The propensity to play is a biological system for promoting rapid adaptation to threats to survival that cannot be predicted. Playfulness, then, is characteristic of animals that make a specialty of being adaptable, and is a prime capability in changing and changeable settings (Ellis, 2015, p. 444)."

Interconnected Components and Processes. As a complex, dynamical system, the brain consists of billions of varied neurons and neuron networks that can interconnect across specialized regions by electrical and chemical transmissions modifiable by genetic and environmental influences (see Marcus & Freeman, 2015; Richardet, Chappelier, Telefont, & Hill, 2015). For example, the amygdala region monitors and helps to adapt to changes in threat levels, thereby providing emotional gatekeeping for cognitive processes. 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, self-regulation, creative thinking, problem solving, and the arts (see also Blair & Raver, 2012). Strengthening the amygdala strengthens these interrelated capacities. The term "emotional intelligence" (Goleman, 1995) has become a popular way to think about the importance of these connections. It is therefore significant that professional educators know how to maintain reasonable challenges and scaffolds in order to support optimal learning and young children's sense of competence.

Oscillations and Synapses—Pluripotentiality. Young children's enactment of their imaginations through observable play experiences can represent how the brain functions as a nonlinear dynamical system. The brain's physiology of communication

and developmental trajectories involve *synapses*, the ongoing *relationships across chemical spaces between* the dendrites, and axons of the neurons in the brain. The *axon*(*s*) within the neuron transmit electrical signals and the many branching *dendrites* could receive signals from axons (Kelso, 1995, p. 231. See also Mitra & Bokil, 2008). The synapses are oscillating chemical or electrical signals that integrate across the various functional aspects of the brain, an oscillation between local and global regions, a process of *pluripotentiality*. Each neuron has the capacity to both receive and inhibit stimuli, a nonlinear oscillation process that re-balances the neuronal connections across synapses. Oscillations regulate neural thresholds and refractory periods.

Oscillations and Learning. The strength of synaptic coupling within the oscillation process (at varying rates) can change through learning. It is possible for new dendritic connections to form (Shelton, 2013). "[W]hen two or more nonlinear oscillators couple nonlinearly, the process of self-organization renders a wide variety of behaviors possible" (Kelso, p. 243).

Brain Grammar. Thus, similar to children's play, the brain functions as a self-organizing system of phase transitions with bifurcations "Brain maturation exhibits pattern and order that emerges from interactions of many different components, including those that are part of the play development dynamic system" (Bergen et al., 2016). Similar to the nonlinear functioning of children's play interactions, the underlying processes of the brain conform to a predictable *grammar* with unpredictable connections. Think about the enmeshed *intra-* (personal or intra-neuron), *inter-* (interpersonal or interneural and neural networks), and *extra-* (environmental context) processes.

Neuroplasticity and Self-organization. Neuroplasticity is the particular characteristic of the brain that is most active in young children as they play and make multitudes of connections. Neuroplasticity refers to the capacity for dendritic connections to form and networks to reorganize within the dynamic of experience that represents learning and the adaptation to new behavioral tasks (Mitra & Bokil, 2008; Shelton, 2013). The generative plasticity of the brain "is largely due to networks of [neurons] . . . rather than the sum of independent effects of individual [neurons]" (Mitchell, 2009, p. 275). The networks can serve as efficient attractors that support self-organization. Within these modifications, networks both absorb and generate complex brain functions (Cicurel & Nicolelis, 2015; Shelton, 2013). In turn, there are potentially rich and complex connections across the brain that support the development of myelination of the axons. Myelin layering, insulating the axons, improves the strength of connections and the speed of electrical connections (Chudler, n.d.; Hanline, 2008; NGIDD Consortium, 2010).

Pruning. There is a *paradox of plasticity*, however, in the process of *pruning* myelin. On the one hand, when children are in environments where there are rote instruction and limited opportunities for play and action-based learning experiences, there is pruning of the brain's less used rich network of myelinations. On the other hand, the brain benefits from pruning which supports and helps to focus the

most often used connections that can support learning (Gopnik, Meltzoff, & Kuhl, 1999; Tang et al., 2014).

In effect, the brain's neural networks create models of the world and simulate them into the future; and along the way, the neural networks rewire themselves (Kaku, 2014). It is noteworthy that Lev Vygotsky wrote of imagination and creativity: "A person's creative activity does essentially this: it attends to the future, creating it, and changing the view of the present" (1990, p. 85). He saw imagination and creativity related to cultural context. Note that children's sociodramatic play develops unpredictably within the cultural event knowledge of the players.

In recent years, technological developments with functional MRIs and other technologies have added to the historical physical study of brain tissue. However, there are additional frontiers yet to confirm physiological dynamics (see Marcus & Freeman, 2015; Richardet et al., 2015). In the meanwhile, observing the nonlinear, dynamical functioning of young children's imaginative play provides an additional basis for illuminating how learning takes place. The narrative continues with discussion of the dynamic themes curriculum approach that mirrors the ways in which young children learn by participating in activity-based, content-rich, and meaningful environments.

Dynamic Themes Curriculum

Dynamic themes are predictable, isomorphic (self-similar) configurations/imagery patterns that underlie the multiple, surface forms that could represent them. For example, the dynamic theme *cyclic change* imagery appears in the history of society, animal, human, and plant growth; weather; evaporation; phases of the moon; and other objects that change across time. *Dialectical contrast/conflict* dynamic theme imagery appears in human conflicts; voting; economic scarcity; magnetism; and musical counterpoint. The dynamic theme *synergy* (the whole exceeds the sum of its parts) imagery appears in chemical processes; explosive events; growth and reproduction; economic processes; musical arts; square dancing; dramatic arts; collaborative constructions; and poetic arts (see Fromberg, 2012).

So, the underlying dynamic theme imagery is predictable across disciplines but the various surface forms are unpredictable. *Meaning takes place within the phase transition between the underlying and the surface forms*. In effect, the underlying dynamic theme imagery has the inherent potential to become represented in many surface forms as phase transitions connect by way of fractal attractors to create isomorphic imagery.

Grammar of Early Experience. Dynamic themes function as an analogical *grammar* of early experience and serve as underlying attractors; the underlying imagery of finite patterns can generate infinite possibilities. It is within the transformation (phase transition/bifurcation) between the deep and surface forms that meaning can occur. Isomorphism refers to "the generative process by which the underlying

dynamic-theme relationships may take different surface forms. Analogies, built from cognitive connections based upon personal experiences, help humans to infer isomorphic connections" (Fromberg, 2015, p. 419).

Complexity theory explores nonlinear, dynamic, seemingly random experiences and phenomena that, different on the surface, manifest underlying regularities. From a psychologist's perspective, "Based on random interaction, [fractal construction] reveals the holistic quality of the underlying pattern …. The same fractal attractor inevitably emerges out of chaotic trajectories" (Marks-Tarlow, 2008, p. 260). Within this nonlinear framework, dynamic theme imagery provides foundational support for the ongoing educational development of phase transitions and bifurcations. Indeed, sensitive teaching involves the creation of potential phase transitions by the timely provision of resources, spaces, and opportunities.

Dynamic Theme Grammar and Brain Grammar. Paralleling these curricular concerns, neuroscientists contend that the neural networks of the human brain support these flexible and transformational processers (Payne & Kounios, 2009; 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). The underlying dynamic theme imagery parallels the "local" whereas the multiple forms of cross-disciplinary experiences parallel the "global" functions.

Scaffolds Revisited. When educators provide exposure to experiences that represent a particular dynamic theme, children become receptive to perceiving that imagery within other diverse surface representations that can expand and deepen meaningful learning. In effect, dynamic themes are teacher scaffolds that adapt action-based learning experiences to young children's capacities to integrate challenges and fresh phase transitions. Thus, meaningful, quality teaching-learning and learning-teaching relationships are complex adaptive systems of coupled dynamics.

It is worth mentioning that meaningful activity-based experiences that represent concepts within, and tools of, the social sciences and sciences afford young children reasons to represent their grasp of meanings in two- and three-dimensional forms, in effect, speaking, writing, drawing, and constructions. Content-rich meanings also afford young children reasons to measure and calculate through the tools of mathematics.

Concluding Statement

Young children's sociodramatic and construction play can reveal the nonlinear dynamical system's grammar of their brain development. In turn, the underlying grammar of their play supports the educational development of dynamic themes as an active, meaning-based grammar of experience.

The discussion strands in this chapter embody the fractal nature of developmental trajectories along with the powerful value of oscillations between (1) integrative

structures in the brain as well as within (2) the grammar of play and (3) the grammar of experience. Educators who envision these dynamical processes—and have strong grounding in meaningful content bases that are transdisciplinary—are well equipped to nurture phase transitions and bifurcations that expand and deepen children's knowledge bases and executive functions, including self-regulation. In effect, self-regulation grows out of experiences that are interpersonal as well as environmental-personal.

There are implications for educational practice that are based upon the nonlinear dynamics of children's development through play with objects and other children as well as from curriculum that includes other engaging, action-based, and meaningful experiences.

- "The challenge for professional educators is to create happenings/basins of attraction with children that balance both planning and adaptation to emerging events (Fromberg, 2015, p. 431)." Educators can meet the challenge by welcoming more than one interpretation of an issue or solution to a problem. They also can refine questioning skills that ask for children's perceptions, ideas, opinions, and reactions rather than merely isolated facts or yes-no responses. The focus is on the dynamics of children's learning and connection making as well as setting and solving problems.
- Educators who recognize that different children who engage in different activities at different times might have equivalent experiences have the power to be flexible. This principle suggests that educators could adjust to the variety of children's perspectives and their ways of learning by planning experiences and resources that welcome the *multiple ways* in which to represent underlying dynamic themes in activity-based formats. Formats could span concepts that use the tools of different disciplines as their representational forms.
- Thus, educators would focus on supporting children to make connections between events. They create cognitive dissonance when they create a basin of attraction, in effect, the opportunity for a comparison between expectation-experience-and-surprise comparison between the expectation and experience. Therefore, professional educators focus on nonlinear transactions, continuous communication (Davis & Sumara, 2006), and multiple forms of assessments to inform planning and instruction rather than uniform presentations and expectations. This focus supports children's capacity for self-organization and executive function. The focus is on children's exposure to isomorphic imagery and connections through vivid imagery and integrative concepts.
- The educator's role, furthermore, includes providing culturally relevant pedagogy with shared responsibility for planning. Such an educator engages in interpretive/ethical reflection (Van Manen, 1990). Flexible, extended time schedules, with mostly smaller groups, and collaborative as well as individual activities, could strengthen children's self-motivation, self-regulation, and positive attitudes toward education.

Moreover, a dynamic themes approach to curriculum could help both educators and children to feel empowered and to look forward to having great expectations for the future.

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