*Journal of Curriculum and Supervision*
Winter 1992, Vol. 7, No. 2, 115–130



# RECONCEPTUALIZING LEARNING AS A DYNAMICAL SYSTEM

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Few educators believe that the complex processes contributing to learning in classrooms occur randomly or chaotically. Quite the contrary, most argue that there is an order in classrooms that is stable and repeatable and ultimately allows students to achieve. Curriculum guides are written, textbooks selected, and teachers trained to ensure the presence of certain critical ingredients required for "effective instruction." Yet, despite the care and control involved in the educational process, wide discrepancies appear when students are evaluated. Educators point to the variables that influence the quality of the learning process: the heterogeneity of learners, economic disparity among school districts, and questionable teaching practices.

Dewey has compared the integrative nature of education to an ecosystem where each component influences and is influenced by every other.[1] To understand the learning process in schools, we must understand a complex set of contextual and instructional conditions. The quantity and the extent of interdependence among these factors contributes to the difficulty in precisely examining the educational process. Traditionally, educational researchers have used reductionist research designs that deconstruct the learner, the instruction, and the curriculum into increasingly smaller components.[2] We have assumed that learning was inherently linear and stable.

Recently, we have used interpretive research paradigms to examine larger, more complex sections of the educational ecosystem. This research has given us a more complete understanding of the school setting. Never-

[1]For further description of the ecological perspective in education, see John Dewey, *Democracy and Education* (New York: Macmillan, 1916), Tom Colwell, "The Ecological Perspective in John Dewey's Philosophy of Education," *Educational Theory* 35 (Summer 1985): 255–266, Ann E. Jewett and Catherine D. Ennis, "Ecological Integration as a Value Orientation for Curriculum Decision Making," *Journal of Curriculum and Supervision* 5 (Winter 1990): 120–131. Scholars in ecological psychology are also studying dynamical systems. For a summary, see Daniel Stokols and Irwin Altman, eds., *Handbook of Environmental Psychology*, vol. 1 (New York: Wiley, 1987), pp. 7–40

[2]Gary A Cziko, "Unpredictability and Indeterminism in Human Behavior: Arguments and Implications for Educational Research," *Educational Researcher* 18 (April 1989): 18.

theless, developing the conceptual networks to articulate relationships across interpretive findings remains a difficult process. A more holistic approach to complexity—described as dynamical systems theory—may better explain the integration and connectedness within the learning process.

Dynamical systems theory provides a framework for defining and examining critical components in complex, evolving environments. The theory offers rich models or metaphors to guide how we view complex ecosystems like those involved in learning. Because these models have known dynamic properties, we can compare empirical evidence for patterns and inconsistencies. Among the most relevant properties in the dynamical ecosystem are those associated with *attractors*—major variables that influence or attract surrounding elements—and *constraints*—secondary factors that mediate attractors' power to control the ecosystem. Applied to the educational ecosystem, this perspective shows how a few strong attractors acting within a number of learner, instructional, and contextual constraints influence learning.

Here I use dynamical systems theory to suggest a heuristic for examining the educational process as a holistic, connected, and interdependent system. Although the dynamical systems literature uses the term *system*, it does not imply a linear, plodding process that offers little hope to address educational complexity. Instead, the theory uses various metaphors to evoke evolving, self-organizing networks that create order out of chaos. Our colleagues in the natural and behavioral sciences label these processes *dynamical systems.*

## DYNAMICAL SYSTEMS THEORY

Much effort in education is expended to promote the quality of the teaching-learning process and guarantee the integrity of learning outcomes. Most educators would argue that the educational process is anything but random. Yet despite these efforts to legislate and mandate quality, even students who have successfully demonstrated specific knowledge gains immediately following instruction may not retain that information when tested 6 to 12 months later. This failure to retain knowledge is clearly a problem when we define learning as a permanent change in behavior. Although the educational process is carefully constructed, learning outcomes do not always mirror our intentions.[3]

In addition, we cannot continue to ignore the ever-increasing number of students who do not appear to perform successfully in the school environment.[4] Traditionally, we have addressed these problems through

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[3]Catherine Combleth, "Curriculum In and Out of Context," *Journal of Curriculum and Supervision* 3 (Winter 1988): 86

[4]See, for example, Lisa D Delpit, "The Silenced Dialogue Power Pedagogy in Educating Other People's Children," *Harvard Educational Review* 58 (August 1988) 280–298; Reba N. Page, "Games of Chance The Lower-Track Curriculum in a College-Preparatory High School," *Curriculum Inquiry* 20 (Fall 1990) 249–281

tighter administrative controls on curriculum, teacher-proof instruction, and increased student homogeneity through tracking.[5] Yet if we analyze the learning process that some students experience, we might well be forced to conclude that it is random and chaotic.

Seemingly random behavior also intrigues and frustrates scientists in other disciplines Crutchfield and his colleagues have described an apparently stationary dust particle that, when viewed through a microscope, seemed to be continuously jiggling in an erratic motion.[6] These physicists pointed out that surrounding water molecules in thermal motion were continuously bombarding the dust particle. They explained that "because the water molecules are unseen and exist in great number, the detailed motion of the dust particle is thoroughly unpredictable."[7] In this system, the highly connected networks of influential subcomponents become so entwined that the resulting pattern of behavior seems chaotic.

Lorenz's analysis of weather systems has expanded our understanding of complex connections that lead to randomness.[8] Although meteorologists, like educators, can often predict short-term occurrences, they cannot reliably forecast long-range outcomes. Lorenz has shown through mathematical modeling that microscopic changes in the initial conditions affecting weather systems are compounded as they flow through the system. Major variations in observable events result. Although the phenomena appear to act randomly, the chaos is the result of variations in the initial conditions that are magnified or compounded as they progressively interact with critical factors in the system.

Cziko has argued that dynamical or chaos theory has important implications for understanding human performance.[9] The theory asserts that, although the initial relationships between two variables may appear simple and deterministic, a less visible nonlinear relationship may still exist. Outcomes that we cannot predict at all using traditional reductionist research designs may result Dynamical systems theorists can examine the substantial variations in student learning in carefully controlled educational environments Small differences in the learner, social, political, and economic context of schools may lead to dramatic changes in student learning within a single

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[5]Robert E Slavin, "Ability Grouping and Student Achievement in Elementary Schools. A Best Evidence Synthesis," *Review of Educational Research* 57 (Fall 1987): 293–336.

[6]James P Crutchfield, J Doyne Farmer, Norman H. Packard, and Robert S Shaw, "Chaos", *Scientific American* 255 (No 6, December 1986): 46

[7]Ibid

[8]Edward N Lorenz, "Large Scale Motion of the Atmosphere. Circulation," in *Advances in Earth Science*, ed Patrick M Hurley (Cambridge: Massachusetts Institute for Technology Press, 1966), pp 95–109

[9]Gary A Cziko, "Unpredictability and Indeterminism in Human Behavior: Arguments and Implications for Educational Research," *Educational Researcher* 18 (April 1989): 19

lesson. When the large number of explicit and hidden variables form an interdependent network, the process may become convoluted and imbalanced to the point that learning appears chaotic.

Sawada and Caley have stated that in dynamical systems imbalance or disequilibrium is perceived as part of a positive metamorphosis.[10] A new way of ordering the system often evolves from the random or chaotic behavior. New patterns may emerge in a self-organizing process as the system shifts toward a novel, internally initiated, and determined state.[11]

We can view aspects of the learning process itself as a self-organizing system. When alert, motivated students confront new information that conflicts with knowledge already learned, a sense of disequilibrium may occur as they try to understand and integrate the novel, disconcerting concept into a previously stable knowledge structure.[12] Students then appear to experience cognitive dissonance that throws the current knowledge structure into disequilibrium. New understandings replace old ones. The critical questioning that occurs sends the normally ordered, logical thought processes into chaos. Learners experiencing this process may report feelings of confusion, frustration, and excitement as they incorporate new components into the knowledge structure, laboriously positioning the new ideas into a satisfactory coherence Educational scholars may experience similar feelings when trying to understand and accommodate a new theory like dynamical systems.

The effort to link the new knowledge with previously learned information leads to instability. Major changes described as *bifurcations* create a new conceptual structure. Each time we add new knowledge, we destabilize the learning process, thus necessitating additional reorganization and restabilization. Further, the learning process as a self-organizing system appears quite selective. The cognitive system does not respond to each novel concept presented. Many teachers say that students do not always learn or choose to

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[10]Daiyo Sawada and Michael T Caley, "Dissipative Structures New Metaphors for Becoming in Education," *Educational Researcher* 14 (March 1985), 17.

[11]Barry F. Madore and Wendy L. Freedman, "Self-organizing Structures," *American Scientist* 75 (May–June 1987), 253.

[12]Christine A Skarda and Walter J. Freeman, "How Brains Make Chaos in Order to Make Sense of the World," *Behavioral and Brain Sciences* 10 (June 1987) 172. Cognitive psychologists have used semantic networks or knowledge structures to describe individuals' conceptualizations of declarative knowledge. Knowledge structures demonstrate both the major concepts and the perceived relationships that exist among the concepts We learn as we effectively position new information in the evolving knowledge structure. Researchers are using knowledge structures to monitor cognitive change during curricular or instructional interventions. See David H Jonassen, "Assessing Cognitive Structure: Verifying a Method Using Pattern Notes," *Journal of Research and Development in Education* 20 (Spring 1987): 1–14; Moshe Naveh-Benjamin, Wilbert J McKeachie, Yi-Guang Lin, and David G Tucker, "Inferring Students' Cognitive Structures and Their Development Using the 'Ordered Tree Technique,'" *Journal of Educational Psychology* 78 (April 1986): 130–140; David B Strahan, "How Experienced and Novice Teachers Frame Their Views of Instruction: An Analysis of Semantic Ordered Trees," *Teaching and Teacher Education* 5 (No. 1, 1989): 53–67.

learn knowledge presented in the classroom. Instead, learners respond to only those experiences they find meaningful.[13] Shuell has suggested that relevance is associated with the presence of related prior knowledge and the learner's ability and motivation to position new information into the knowledge structure [14] Without these critical components, the learner's knowledge structure will remain stable, and thus, learning will not occur.

The complex self-organization occurs as the learning process internally regulates and maintains itself in an optimal state. The self-organizing nature of the dynamical process facilitates the evolution of increasingly sophisticated thought processes that respond to the complexity of the learning environment. Inherent in learning are attractors and constraints that influence and mediate the dynamical process.[15]

*Attractors*

Dynamical systems have preferred states of stability. These states, or attractors, balance the process and lead to predictable behavior. Attractors represent specific modes of organization and levels of effort that, if left undisturbed, will appear as typical states of functioning. Conversely, when perturbed, the system may be forced to move away from this preferred regimen, demonstrating behaviors within a range of activity. For instance, perturbation to a teacher's carefully planned lesson may occur in the form of a disruptive student who forces the teacher to revise, temporarily, the goals for the lesson. Once that student is no longer present, however, the teacher settles back into the previous preferred teaching pattern. The attractor here is probably not the lesson plan itself but the teacher's beliefs or value orientations manifested in the planning and teaching process.

Educational value orientations determine, in part, the nature of the lesson and the teacher-student interactions.[16] Value orientations appear to be relatively stable philosophical structures that are not easily perturbed. They influence a number of curricular, instructional, and evaluative decisions throughout the educational ecosystem. Relatively small perturbations, such as

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[13]Gary A Cziko, "Unpredictability and Indeterminism in Human Behavior: Arguments and Implications for Educational Research," *Educational Researcher* 18 (April 1989): 18

[14]Thomas J Shuell, "Cognitive Conceptions of Learning," *Review of Educational Research* 56 (Winter 1986): 416.

[15]Esther Thelen, "Self-organization in Developmental Processes: Can Systems Approaches Work?" in *Minnesota Symposia on Child Psychology: Systems and Development*, vol. 22, ed. Megan R. Gunnar and Ester Thelen (Hillsdale, NJ: Erlbaum, 1989), pp. 77–115.

[16]For a detailed presentation of the role of value orientations in curricular decision making, see Elliot W Eisner and Elizabeth Vallance, eds., *Conflicting Conceptions of Curriculum* (Berkeley, CA: McCutchan, 1974); John D. McNeil, *Curriculum: A Comprehensive Introduction*, 3rd ed. (Boston, Little, Brown, 1985).

a disruptive student, are unlikely to create a long-term change in a strong value attractor.[17]

Attractors act as bowls or basins where observable behaviors pool. Stable systems have deep attractor basins. Behaviors associated with the teaching-learning process are similar to objects drawn by gravity into the center of the basin. The attractor's stability controls and limits objects' range of movement, just as the stability and controlling nature of value systems mediates the acceptance or rejection of content or methods from competing perspectives.

It takes a powerful, dynamic event to disturb the system to the extent that objects are lifted up out of the attractor basin and drawn toward an alternate basin.[18] Similarly, it takes a major event to cause a stable value orientation to change or spontaneously reorganize into a new value perspective.

Conversely, teacher beliefs that are not strongly held are less stable attractors that resemble a shallow pan rather than a deep basin. When perturbed or challenged, the teacher may be willing to develop new perspectives to address the situation. In dynamical systems terminology, the object or behavior slides out of the shallow attractor basin and is drawn into the field of a competing attractor.

*Values as attractors for learning.* Value orientations act as powerful attractors in the school ecosystem. For instance, teachers' value orientations may serve as attractors for their preferred teaching styles. Teachers frequently favor the format that they believe best communicates their subject matter to students. Years of experience and success often encourage the development of deep attractor basins manifested in lecture and practice formats. Many teachers' attractor basins are so deep and stable that the range of observable behaviors is limited to a small set. Sawada and Caley have argued that efforts to introduce novel approaches or to promote change through staff development are met with "awesome stabilizing forces."[19] Often in staff development, teachers perceive proposed curricular or instructional revisions as mild perturbations for them to tolerate—and so fundamental change does not occur.

Conversely, some students' value attractors may result in learning styles that exemplify shallow attractor basins. These students learn using various styles depending on how the material is presented.[20] They may flow easily from style to style, learning equally well from a lecture format or small-group

[17]Christine A Skarda and Walter J Freeman, "How Brains Make Chaos in Order to Make Sense of the World," *Behavioral and Brain Sciences* 10 (June 1987): 164.

[18]Esther Thelen, "Self-organization in Developmental Processes. Can Systems Approaches Work?" in *Minnesota Symposia on Child Psychology. Systems and Development*, vol. 22, ed Megan R. Gunnar and Ester Thelen (Hillsdale, NJ Erlbaum, 1989), pp. 77–115

[19]Daryo Sawada and Michael T. Caley, "Dissipative Structures New Metaphors for Becoming in Education," *Educational Researcher* 14 (March 1985). 16.

[20]Olivia N Saracho, "Cognitive Styles and Classroom Factors," *Early Child Development and Care* 47 (June 1989): 149–157.

discussion. Adapting and changing to different learning conditions poses few problems. Other students, however, may have deep attractor basins associated with a preferred learning style. They may depend on direct teaching formats to emphasize the most critical material for learning. They do not appear to be able to learn independently and are noticeably frustrated when asked to complete an assignment with minimal direction or assistance.[21]

*Dimensions of value attractors.* Several dimensions or levels of value attractors may act and interact in the learning process: the conscious or unconscious values held by students, teachers, administrators, and school board and community members. For instance, we might imagine the values and beliefs that define schools' bureaucratic structure, described by Collins as "educationocracy," as a top-level attractor in a top-down management system.[22] The nature of the rules and policies that determine the curriculum, the guidelines for teacher performance, and the expectations for student behavior are carefully monitored.

Advocates of this process promote it as a means of creating effective schools where all teachers and students have equal access to classrooms, materials, and knowledge. Educational values serve as a deep attractor basin for the organization, effectively encouraging a stable, limited set of participant behaviors. Alternative modes of operation, such as new teaching methods or new organizational formats, are encouraged as long as they are consistent with the set of approved policies. There is room for difference, but only within the steep walls of the deep attractor basin.

Critical pedagogists, in contrast, point to these factors as oppressive.[23] The walls of the basin effectively limit our opportunity to respond to the diversity that they believe is inherent and necessary in social systems.[24] The depth or strength of the educational attractor basin to control behaviors may limit some students' learning, and it may alienate teachers who require more flexibility and freedom than the organization allows.

Teachers' own value attractors may be the most influential factors in curricular decision making. In nonacademic subject areas that do not rely on textbooks—art, music, and physical education—teachers' value orientations often dominate the curriculum selection process. Ennis, Mueller, and Hooper

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[21]Ibid., p 150.

[22]Randall Collins, "Some Comparative Principles of Educational Stratification," *Harvard Educational Review* 47 (February 1977): 7.

[23]See, for example, Michelle Fine, "Silencing in Public Schools," *Language Arts* 64 (February 1987). 157-174, Henry A Giroux, "Curriculum Theory, Textual Authority, and the Role of Teachers as Public Intellectuals," *Journal of Curriculum and Supervision* 5 (Summer 1990). 361-383, Roger I Simon, "Empowerment as a Pedagogy of Possibility," *Language Arts* 64 (April 1987). 370–382.

[24]Ivor F. Goodson, "Studying Curriculum. Towards a Social Constructionist Perspective," *Journal of Curriculum Studies* 22 (July–August 1990): 299.

have reported that teachers' visions for student learning influence most of their curricular decisions.[25] During staff development sessions, teachers more willingly accepted and used innovative teaching suggestions that were consistent with their beliefs about student learning. Although this finding makes intuitive sense, many curriculum development initiatives are funded and implemented with little sensitivity to teachers' value attractors.

Students' motivation and interest demonstrate another dimension of beliefs about learning in the classroom. Students' values at times conflict with teachers' or administrators' beliefs about learning. Learners who experience direct conflicts between the content taught in schools and the knowledge they consider necessary for survival in society may themselves be operating from deep attractor basins.[26] Although attractors constitute a powerful influence on learning, they themselves operate within constraints that mediate their control over the educational ecosystem.

### *Constraints*

Constraints are limiting factors that affect the attractor's freedom to control outcomes.[27] Although the school may try to influence individual students' learning, the background experiences and prior knowledge each learner brings to the educational environment constrains the school.[28] Constraints evolve with each attractor. Attractors and constraints continuously destabilize and reform to better address the contextual and instructional process. Critical questions concern the relevant constraints that mediate qualitative change in learning for particular students working in specific instructional and contextual environments. Three major constraints work in complex educational systems. the learner, the instruction, and the context.

*Learner constraints.* These constraints represent learners' unique characteristics that modify the learning process.[29] Most research now conducted

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[25]Catherine D Ennis, Leslie K. Mueller, and Linda K. Hooper, "The Influence of Teacher Value Orientations on Curriculum Planning within the Parameters of a Theoretical Framework," *Research Quarterly for Exercise and Sport* 61 (March 1990): 360–368

[26]Gary G Wehlage, Robert A. Rutter, Gregory A. Smith, Nancy Lesko, and Ricardo R. Fernandez, *Reducing the Risk: Schools as Communities of Sport* (London Falmer Press, 1989)

[27]Karl M Newell, "Constraints on the Development of Coordination," in *Motor Development in Children: Aspects of Coordination and Control*, ed. M. G. Wade and H. T. A. Whiting (Boston: Martin Nijhoff, 1986): 350.

[28]See, for example, Lisa D. Delpit, "The Silenced Dialogue: Power and Pedagogy in Educating Other People's Children," *Harvard Educational Review* 58 (August 1988): 280–298; Reba N. Page, "Games of Chance: The Lower-Track Curriculum in a College-Preparatory High School," *Curriculum Inquiry* 20 (Fall 1990): 249–281.

[29]See, for example, Signithia Fordham, "Racelessness as a Factor in Black Students' School Success: Pragmatic Strategy or Pyrrhic Victory," *Harvard Educational Review* 58 (February 1988) 54–84; Tamara Lucas, Rosemary Henze, and Ruben Donato, "Promoting the Success of Latino

in U.S classrooms and schools acknowledges learners' heterogeneity. This diversity is discussed as individual differences associated with culture, ethnicity, gender, socioeconomic class, language, handicapping condition, and intellectual and physical ability. According to the research, these factors restrict or promote student learning.

Witkin has suggested that perceptual differences also influence how well students understand information and find meaning.[30] More recently, Frank has argued that limitations in memory-storage capacity, the ability to search and retrieve information from memory, and levels of mental energy may significantly constrain learning.[31] When students cannot identify and remember information, their ability to demonstrate learning is severely inhibited.

Other hidden constraints—learner expectations, self-concept, and locus of control—diminish opportunities for students to pursue their interests. Lucas, Henze, and Donato have suggested that language-minority students are often blamed for underachieving in schools: "By considering them 'difficult' or culturally and linguistically 'deprived,' schools have found it easy to absolve themselves of responsibility for the education of these students."[32] But when teachers consider ethnicity an important aspect of identity, they design programs that use the students' cultural and language strengths to make learning easier.

*Instructional constraints.* Instructional constraints consist of the school- and teacher-designated content, methods, and materials selected specifically for their perceived effect on student learning. Although some curriculum materials provide a valuable resource for teachers, Apple has argued that textbooks funnel learning behaviors and experiences into specific time-honored formats, limiting teachers' creativity.[33] Kirk has noted a similar problem with curriculum packages.[34] He asserts that the school knowledge represented in curriculum packages is not fixed, but

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Language-Minority Students: An Exploratory Study of Six High Schools," *Harvard Educational Review* 60 (August 1990) 315–340; Alan Peshkin and Carolyne J. White, "Four Black American Students: Coming of Age in a Multiethnic High School," *Teachers College Record* 92 (Fall 1990): 21–38.

[30]Herman A Witkin, *Cognitive Styles in Personal and Cultural Adaptation* (Worcester, MA: Clark University Press, 1978).

[31]Bernard M. Frank, "Effects of Information Processing on the Memory of Field-dependent and Field-independent Learners," *Journal of Research in Personality* 17 (Winter 1983): 89–a96.

[32]Tamara Lucas, Rosemary Henze, and Ruben Donato, "Promoting the Success of Latino Language-Minority Students: An Exploratory Study of Six High Schools," *Harvard Educational Review* 60 (August 1990): 316.

[33]Michael W Apple, "Curricular Form and the Logic of Technical Control: Building the Possessive Individual," in *Cultural and Economic Reproduction in Education: Essays on Class, Ideology, and the State*, ed. Michael W. Apple (London: Routledge & Kegan Paul, 1982), pp. 247–274; Michael W. Apple, *Teachers and Texts: A Political Economy of Class and Gender Relations in Education* (New York: Routledge & Kegan Paul, 1986).

[34]David Kirk, "School Knowledge and the Curriculum Package as Text," *Journal of Curriculum Studies* 22 (September–October 1990): 409–425.

structured according to the interests of particular groups . . . The significance of this insight lies in the fact that many students are unjustly disadvantaged in and by their school experiences as a result of the influence of these interest groups.[35]

Further, the design of the learning environment and the presentation of information to students may constrain learning. The literature on the concept of effective teaching articulates in detail critical components necessary to facilitate learning. These components include opportunities for students to be involved with the content and to work at an appropriate level of difficulty based on their level of prior knowledge and expertise with the topic. If, because of ineffective teaching, students do not have access to the knowledge that *they* consider important, then their learning is significantly constrained.

Page has described the teaching-learning process in a lower-track secondary curriculum as a "game of chance."[36] Teachers using the lower-track curriculum did not develop content connections between new knowledge and prior knowledge necessary for learning. Students found the curriculum boring and meaningless.[37] Based on their perceptions of the school's benefit to them, lower-track students either acquiesced or resisted the repetitious format. Those who acknowledged the school's contribution to their career objectives accepted their passive role, but students who did not perceive these benefits were disdainful and rebellious.[38]

*Contextual constraints.* A third category of constraints includes social, economic, and political conditions that control or facilitate opportunities for learning. Contextual constraints often appear as multiple, contradictory, and overlapping perspectives that directly or inadvertently shape school and community policy.[39] Economic factors emanating from the power base dictate how we use resources to facilitate some students' growth while inadvertently or purposefully limiting other groups' opportunities. Political constraints act as powerful forces to modify the teaching-learning process.

Giroux has suggested that these forces often lead to oppression, inequa-lity, and silencing in school and social systems.[40] Delpit has described the conflicts that can arise when children do not come to school with the "cultural capital" necessary to perform effectively within the traditional majority, middle-class context in schools:[41]

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[35]Ibid., p. 409.

[36]Reba N. Page, "Games of Chance. The Lower-Track Curriculum in a College-Preparatory High School," *Curriculum Inquiry* 20 (Fall 1990). 249–251

[37]Ibid., p. 261.

[38]Ibid., p. 273.

[39]Nicholas C. Burbules, "A Theory of Power in Education," *Educational Theory* 36 (Spring 1986): 95–114; Elizabeth Ellsworth, "Why Doesn't This Feel Empowering? Working through the Repressive Myths of Critical Pedagogy," *Harvard Educational Review* 59 (August 1989): 297–324

[40]Henry A. Giroux, "Radical Pedagogy and the Politics of Student Voice," *Interchange* 17 (Spring 1986): 48–69.

[41]Michael W. Apple, *Ideology and the Curriculum* (Boston: Routledge & Kegan Paul, 1979)

Many liberal educators hold that the primary goal for education is for children to become autonomous, to develop fully who they are in the classroom setting without having arbitrary, outside standards forced upon them. This is a very reasonable goal for people whose children are already participants in the culture of power and who have already internalized the codes. But parents who don't function within that culture often want something else. . . . They want to ensure that the school provides their children with discourse patterns, interactional styles, and spoken and written language codes that will allow them success in the larger society.[42]

Dynamical systems theory describes the intricate processes that act at different levels of complexity. Attractors and constraints may function within larger, more comprehensive attractor and constraint networks—for instance, the value structures in individual classrooms, schools, and the community. The multiple levels of complexity may become highly convoluted, often affecting how well students learn.

Ellsworth has described an example from her university course, "Media and Racist Pedagogies."[43] Ellsworth and her students tried to address sensitive issues of institutional racism while reacting to a community crisis "provoked by the increased visibility of racist acts."[44] Learner, instructional, and contextual constraints all mediated the multiple levels of value attractors. The convoluted process led Ellsworth to question how successfuly she achieved her goal of student empowerment.[45]

## THE COUPLING AND CASCADING OF DYNAMIC ATTRACTORS

When we view learning as a dynamical system, educational decisions couple and cascade, leading to specific achievement outcomes for each student. The dynamics of the process blend and diffuse the influence of attractors and constraints throughout the system.

### *Coupling*

When two or more attractors blend to form a unique perspective, coupling occurs The blending may result in a major change or bifurcation that leads to reorganization within the system. In Ellsworth's course, the opportunity to address racist issues from the perspectives of both majority and minority students created an environment conducive to the formation of new belief structures.[46] Students experienced a curriculum that synthesized or coupled perspectives from class members, the university, and the com-

[42]Lisa A. Delpit, "The Silenced Dialogue. Power and Pedagogy in Educating Other People's Children," *Harvard Educational Review* 58 (August 1988)· 285

[43]Elizabeth Ellsworth, "Why Doesn't This Feel Empowering? Working through the Repressive Myths of Critical Pedagogy," *Harvard Educational Review* 59 (August 1989). 297–324.

[44]Ibid., p. 297.

[45]Ibid., pp. 308–314

[46]Ibid., p. 322

munity. The evolving process illuminated the complex couplings and bifurcations that occurred as class members created shared meanings.

The curriculum observed in schools results from the coupling of various levels of educational beliefs, all combined to form a value profile.[47] Burbules has examined a set of contextual constraints associated with control or power relationships.[48] He describes power relationships in schools as a "web of power" that is both reciprocal and transitive. Here, teachers' value orientations may be forced to couple with the principal's value attractors, thus creating a learning environment that conforms to administrative expectations.

Interacting attractors and constraints play an influential role in defining learning. Attractors acting within specific constraints couple and uncouple as new conditions evolve in the learning process. Some highly stable attractors may destabilize only when perturbed by powerful factors; others may reside in shallow basins and evolve continuously. The depth of the basin and the magnitude of the perturbation determine how much change will occur. The complexity of the system evolves as attractors are coupled and diffused in larger, more comprehensive attractor basins that in turn have their own unique characteristics

### *Cascading*

Cascading refers to the multi-tiered influence of strong attractors as they affect a succession of decisions in the learning process. Value profiles have a distinct influence as they cascade through the multiple tiers of curricular and instructional decision levels. Resolutions adopted at the school board level affect learning experiences initiated at the school and classroom levels. At each level, learner, instructional, and contextual factors that mediate outcomes in the educational ecosystem continue to constrain the cascading effect.

If we elaborate the metaphor of the object moving into and out of attractor basins, we can visualize the influence of coupled value profiles as the learning process cascades from one basin to another. At times, learning is trapped in a powerful attractor manifested in a teacher's teaching style. At other times, it slides over the lip of one basin and into the trough of another. Despite the number of opportunities for diverse programs and methods, the interdependence or coupling of attractors confines the learning outcomes to

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[47]Value profiles reflect a synthesis of value orientations typically found in educational settings. The profile results from the coupling of value attractors that in turn influences curricular and instructional decisions. For an empirical description of teachers' value profiles, see Catherine D. Ennis and Weimo Zhu, "Value Orientations. A Description of Teachers Goals for Student Learning," *Research Quarterly for Exercise and Sport* 62 (March 1991). 33–40

[48]Nicholas C. Burbules, "A Theory of Power in Education," *Educational Theory* 36 (Spring 1986): 104.

a finite set Thus, the educational process appears stable and predictable most of the time, with only intermittent fluctuations.

The observable complexity in the operational curriculum results from the cascading and coupling of the learning process within the attractors and constraints in the educational ecosystem.[49] Traditional, positivistic researchers view the educational setting as a set of causal, linear interactions leading to predictable learning outcomes.[50] The process is a closed system whose whole equals the sum of its parts.

Conversely, in dynamical systems, the coupling and cascading of the attractors magnifies or diminishes each attractor's influence on the final learning product When viewed comprehensively as an open system, the given set of interactions appears chaotic and impossible to define using traditional procedures.

The importance of dynamical systems theory for pedagogical research resides in our ability to conceptualize the changes in learning as part of the coupling and cascading of dynamic attractors. For instance, if decision makers' value profiles are stable attractors, then we should be able to determine how much they actually influence and stabilize the learning process within a set of fairly well known constraints. In classroom settings, the values that cascade from textbooks are coupled with the value attractors of administrators, curri-culum specialists, and lead teachers involved in selecting texts and developing guides. The process remains stable and learning remains predictable as long as the dominant values of the school organization are maintained.

## THE DYNAMICS OF STABILITY AND CHANGE

Dynamical systems maintain their stability through the influence of attractors and constraints. The power of a dynamical system lies in the potential for stability.[51] A stable system can maintain itself in its current state despite major fluctuations in surrounding conditions.

Nevertheless, as Lorenz has demonstrated with weather systems, small perturbations in the initial conditions can couple and cascade through the system, resulting in major changes in the final observable outcomes. For instance, introducing a small, yet personally relevant piece of information may change how a student understands certain content relationships. Small

[49]Catherine D Ennis, "Conceptual Frameworks as a Foundation for the Study of Operational Curriculum," *Journal of Curriculum and Supervision* 2 (Fall 1986). 38.

[50]Gary A Cziko, "Unpredictability and Indeterminism in Human Behavior. Arguments and Implications for Educational Research," *Educational Researcher* 18 (April 1989). 19.

[51]Gregor Schöner and J A Scott Kelso, "Dynamic Pattern Generation in Behavioral and Neural Systems," *Science* 239 (March 1988): 1515.

adjustments in teachers' value structures may contribute to major changes in how they select and present content.

Change or instability can arise solely from the system's dynamics. The equilibrium in the system is lost when an attractor and its concomitant constraints are no longer adequate to maintain the status quo.[52]

Bifurcations occur in the educational process when we no longer consider traditional curricular goals adequate to address evolving learner needs. Attractors shift or switch into different profile basins to accommodate new ideas. Switching may occur as teachers and administrators realize that the content or method does not appear relevant to students.[53] Where the current curriculum is not considered effective, the lack of success acts as a powerful perturbation to destabilize the system, leading to substantial, permanent changes in the educational process. The depth and stability of the attractor basins determines how consistently we will select curricular and instructional options and how much we will modify them to serve learners' specific needs.

Destabilizing forces enter the process when the traditional attractors no longer appear adequate to address the present problem. Wehlage and his colleagues have presented examples of destabilization in school systems that have resulted in a greater emphasis on cultural plurality and programs for at-risk students.[54] These efforts reflect the educational system's attempt to reorganize to better meet the needs and pressures exerted on the learning environment.

As bifurcations begin to evolve within the system at critical points, previously stable behaviors become unstable. The system switches to a different behavior that in turn remains stable until the next critical point. For instance, at one critical point alert, motivated learners try to position new, relevant information within their current knowledge structure. If a major restructuring is required to connect the new knowledge to the prior structure, a bifurcation in the knowledge structure will occur. Before reaching the critical juncture, the system begins to fluctuate between a stable and unstable state. As learners near the critical point, fluctuations in behaviors begin to occur, with longer periods of instability. Change occurs spontaneously as new attractors achieve control of the process.

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[52]Daiyo Sawada and Michael T Caley, "Dissipative Structures New Metaphors for Becoming in Education," *Educational Researcher* 14 (March 1985): 16

[53]Gregor Schöner and J A Scott Kelso, "Dynamic Pattern Generation in Behavioral and Neural Systems," *Science* 239 (March 1988): 1516; Lisa A. Delpit, "The Silenced Dialogue Power and Pedagogy in Educating Other People's Children," *Harvard Educational Review* 58 (August 1988): 2801–297

[54]Gary G Wehlage, Robert A Rutter, Gregory A Smith, Nancy Lesko, and Ricardo R Fernandez, *Reducing the Risk: Schools as Communities of Sport* (Philadelphia. Falmer Press, 1989)

Examples of bifurcations occur in the learning process as values and knowledge structures destabilize and reorganize to address changes in the ecosystem. Although strong attractors like value profiles cascade through the educational system providing stability, at times school or classroom events cause teachers to question their own value perspectives. Teachers' once stable beliefs begin to fluctuate, and their actions appear inconsistent or erratic. As teachers cross the critical point and continue to think reflectively about the consequences of a new perspective, they may spend less time and effort working within their original value perspectives. The new value profile begins to have an increasingly greater power to attract educational decisions, thus influencing student learning.

In professional preparation, researchers have suggested that student teaching is a critical point in the process of learning to teach.[55] For preservice teachers, the opportunity to personally test their formal knowledge in an actual teaching situation may initiate a major bifurcation in value and knowledge structures.[56] Structures that stayed stable throughout their early preparation begin to show some instability during student teaching.[57] Preservice teachers try to position relevant information into their evolving knowledge structure. The knowledge structure at this point begins to develop spontaneously, reflecting many characteristics of a bifurcation within a self-organizing system.

As the parameters of the learning process change, the learning outcomes reflect these changes. Learning is not predictable at certain points in a dynamical system. The learning process is not stable; the system is not at equilibrium. These critical points are frequently associated with spontaneous formations or changes of value or knowledge structures. In student teaching, for instance, critical points may be the access to students, the relevance of a problem, or increased levels of motivation for problem solving that gives impetus to bifurcations. At these junctures, we might be able to describe learning using only a few strong attractors. Dynamical systems theory gives us the opportunity to better understand learning by monitoring the critical points when major perturbations cause change to occur. By monitoring attractors' stability, researchers may be able to determine how much the knowledge structure is likely to change and the form the bifurcation is most likely to take.

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[55]Judith H Placek and Patt Dodds, "A Critical Incident Study of Preservice Teachers' Beliefs about Teaching Success and Nonsuccess," *Research Quarterly for Exercise and Sport* 59 (December 1988): 351–358, Daniel P. Liston and Kenneth M Zeichner, "Critical Pedagogy and Teacher Education," *Journal of Education* 169 (1987): 117–137

[56]Catherine D. Ennis, Leslie K. Mueller, and Weimo Zhu, "Description of Knowledge Structures within a Concept-based Curriculum Framework," *Research Quarterly for Exercise and Sport* 2 (September 1991): 309–318

[57]Ibid.

Dynamical systems theory has the potential to increase our understanding of the constantly evolving learning process. Much current research using experimental and interpretive paradigms focuses on describing the attractors and constraints that stabilize the educational process. Advocates of dynamical systems theory argue for a greater focus on the critical junctures or bifurcations of the process as attractors become unstable. The evolution of learning within multiple attractor basins occurs as we restructure knowledge and values within learner, instructional, and contextual constraints. Using our current understandings of attractors and constraints, we might shift from analyzing stability to examining change. Dynamical systems theory encourages us to focus our attention on the critical junctures in the learning process as beliefs and knowledge spontaneously reform to create order out of chaos.[58]

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[58]I wish to acknowledge the assistance of Dr Jane Clark for comments on a draft of this article