APPLICATION OF COMPLEXITY THEORY TO EDUCATIONAL DECISION-MAKING PROCESS: A MODEL FOR DEMOCRATIC SCHOOL CHANGE

HYU-YONG PARK

Chonbuk National University, South Korea
E-mail: Phy1@jbnu.ac.kr

Abstract - This paper attempts to apply the Complexity Theory as nonlinear dynamics system to educational decision-making process as a metaphor. Different from conventional form of linear and static approaches, the chaotic characters of the Complexity Theory provide nonlinear, dynamic, and creative ways of decision-making process. For the application, this paper adopted three major variables from the Complexity Theory: attractors, bifurcations, and the fractal structure. Based on the three concepts, this paper applied the theoretical implications of the Complexity Theory to a school's case, La Escuela Fratney school, and developed a model for democratic school change. Finally, the implications of this modeling and the application are discussed. This suggested model could broaden the horizon of schools' policy-making practices in more democratic ways, facilitated by diverse, open, and self-regulative movements, rather than linear, directive, and hierarchical processes.

Index Terms - Chaos theory, democracy, educational decision-making process, school policy

I. INTRODUCTION

This paper borrows the major concepts of Non-linear Dynamic System (henceforth, NDS) theory, an overarching term that embraces Chaos theory, Complexity theory, and Catastrophe theory (Guastello, 1995), as metaphor to facilitate this paper's argument (Barratt, 1994). The main argument is that the decision-making process in educational policy is quite analogous to the procedure ruled by the principles and variables of NDS theory. This paper suggests a "Complexity model for EDP," based on three major theoretical components of NDS theory: attractors, bifurcations, and fractal structure.

This paper consists of the following three components: First of all, this paper provides conceptual orientation of this paper's project, and discusses how NDS theory could applied to EDP and how the application benefits the field of educational policy and leadership regarding democratic decision-making in school. Then, this paper introduces some terms and notions of NDS theory, which serve as major components for the Complexity model of EDP that this paper proposes. This model is depicted in a flow chart as a concept map to illustrate the procedure. Finally, this paper applies this model to an actual school's case that has succeeded in reforming the school more democratic.
This paper's theoretical review and application of the chaos model as a metaphor may serve as practical guidelines for teachers or school administrators who want to make a decision for changing their school policies with more democratic way.

II. LITERATURE REVIEW

A. Conceptual orientation
There are two rationales for the inception of this paper. One rationale of this paper's approach is taking a different perspective on the meaning of 'orderliness' in an organizational decision-making process. Orderliness presumes itself as a righteous thing or a desirable status in matters of school and society, while Chaos, its opposite, is considered to be what must be avoided. Thus, the conventional educational theorists may believe that education is responsible for transmitting the 'social order' of current society to children and adolescents. In this case, Order is nothing but an ideology that is trying to maintain the legitimacy of the current system. In this paper, it is argued that order is not always preferable, especially in the practice of EDP, because it may restrict the nature of variable, creative, and democratic ways of EDP. As an alternative approach, this paper argues that the concepts from NDS theories (e.g. Complexity or Chaos theory) can provide meaningful insights in dealing with the issues of EDP, because of the fundamentally different perspectives in interpretation of social and institutional phenomena, as well as its use in explaining natural phenomena.

This is one reason why the application of Complexity theory in EDP is significant. This being said, Geyer & Rihani (2000: 8) provides clear distinction between the notions of order and chaos as shown in the following <Table 1>.

Table 1 Comparison of the traits of order and complexity

Order (Linear)	Complexity (Nonlinear)	Disorder (Anti-linear)
Complete rationality	Bounded rationality	Complete irrationality
Total Certainty	Limited certainty	Uncertain
Predictability	Limited predictability	Unpredictable
Linked causes	Causality is	Causality is

and effects	indeterminate	meaningless
Determinism	Evolutionary change	Chaos

B. Application of NDS theory to EDP

Cambell (1993) argued that complexity can occur in social structures, such as our behavior in making plans, purchasing goods, or selecting one among multiple choices, etc. NDS theory is one way of studying an institution where such complexity exists in its system. According to Cambell, complexity of a system can be defined by several traits: e.g. number and diversity of components, the degree of freedom, the influence of environment, etc. By considering these traits, it is important to determine whether the system is conservative, an equilibrium, a static stage or stable, or it is dissipative, non-equilibrium, phase stage, or unstable. The former traits are for a closed system that is considered to be less complex, and the latter traits are for an open system that yields more complexity.

Furthermore, to apply NDS theory to EDP, the following three points need to be considered: i) whether EDP belongs to an open system; ii) what conditions EDP has; and iii) how we can deal with the complex or chaotic situations. For the first point, Merry (1995) argued that decision-making in human affairs becomes more complex as a result of the mounting number of driving forces, such as increasing populations, new technologies, and rising human expectations. Submit your manuscript electronically for review. For the second point, we have to designate what conditions exist in school's EDP. It is important to define the conditions of school—factors of influence or parameters of variances—that might affect the EDP in the school because, for successful leadership or a decision-making, there is a certain amount of time and preparation needed (Shapiro & Stefkovich, 2016). For the last point, 'chaos' means, in NDS theory, the existence of unpredictable or random aspects in dynamic matters (Poincare, 1952); nonetheless, there is still possibility of getting 'order out of chaos' (Prigogine, 1984) since the system is not static, but dynamic.

C. Democratic decision-making in education

Most educators agree that schools are a crucial locus for training children to become democratic citizens. In this sense, Hochschild & Scovronick (2000: 212-213) emphasize that schools are supposed to provide common core of knowledge and set of values, to model to deal with diverse others, to teach democratic practices, and to provide broad social goal of equal opportunity. NDS theory can be a useful conceptual framework for democratic policy-making initiatives for school. There are studies that applied Chaos theory to educational policy-making for democratic school changes (Ball, 2016, Bowe, Ball, & Gold, 2017) or problem solving in school administration (Dimmock, 2013). Also, a plenty of researches investigated the practices of democratic EDP and suggested various democratic policy-making strategies, such as, leaders' collaborative decision making (Furman & Starratt, 2002; Schoenfeld, 2010) or strategies for making democratic community (Henderson & Kesson, 2004). In the same vein, O'Hair, McLaughlin, & Reitzug (2000) suggested the concept IDEALS, which introduces some characteristics of democratic decision making: inquiry, discourse, equity, authenticity, leadership and service.

III. DEVELOPING A COMPLEXITY MODEL OF EDP

A. Parameters for educational decision-making

1. Attractors: initial phase parameter

In NDS theory, there are mainly three types of attractors: fixed-point attractor, limit cycle attractor, and repellor, which determine whether the system is conservative or dissipative and whether it is chaotic or not. We need to pay attention to what such chaotic attractors induce to EDP and how they influence the decision-making procedure. What we choose for initial conditions will decide what we will experience. One of the important characteristics of Complexity theory is that obstacles are generated from inside, not induced from outside. For example, Fairman & Mackenzie (2015) investigated a high school's decision for student-tracking policy which had to be balanced between teachers' professional leadership and parents' demand. The obstacles, the cacophony inside of the school, prevented the school from reaching agreement in which direction it should pursue its administrative goal. Even if we agree on the general direction in education, any minor factors from the attractors, in their initial conditions as well as their intermediate conditions, could change the course to an entirely unscheduled direction. Still, there are other things we need to take into account in the follow-up phases.

Bifurcations: developmental phase parameter

Bifurcation is a ('control') parameter that is indicative of qualitative changes in the dynamics of nonlinear systems. Bifurcations make the matter bigger; for instance, the way how parents, teachers, and school administrators react to students' delinquent activities may bring them to totally different avenues (Guastello, 1995, 24-25). The significance of bifurcation variables for EDP is in that a tiny change in the phase of bifurcations might result in a huge difference: one single and trifling decision can steer the school to utterly different consequences. For instance, according to Critical Model of Educational Decision Making (Habermas, 1987), there are several agencies that influence a school's decision: provincial government, division board, and district board in the level of instructional structures, and directors, principals, and teachers within the school's administrative system.

The involvement of these agencies can be bifurcation points. It is noteworthy that bifurcations cam make the developmental phases go into a chaotic situation; on the one hand, it is not easy to grasp the situation, clarify the cause of a problem, and make a judgment for appropriate solution. On the other hand, there is an order or a pattern, though it looks complicated. The change of phases is not a static order driven by outer force, but a latent order initiated by an inner self-regulative force. The final phase is the fractal structure, which is explained in the next section.

2. 3. Fractal structure: recursive phase parameter

Fractal structure has self-referential (or recursive) and self-similarity dimensions: though it looks complex, there are self-referentially repetitive patterns with idiosyncratic shapes (Briggs, 1992; Mendelbrot, 1983). Fractal structure in nature shows that it is not a random structure but a systematic, self-referential structure, which has "structural integrity and orderliness" (Cambell, 1993: 162). This paper argues that this principle of fractal structure is also applicable to many practices in EDP. For example, the core foundation for establishing democratic education starts from the genuine democratic decision-making process, from the smallest group or individual level. Similar to fractal structure, democracy on a small scale constitutes democracy on a larger scale. For democratic education, the practice and execution of democracy needs to be started from home, class, school, district, and to the state. A democratic EDP on a small scale, in a classroom, can be a pattern that can be used as a source for self-referential fractal structure for democracy on a larger scale, e.g. in an entire school district. A genuine democratic nation originates in a genuine democratic home or community. Each democratic home reproduces its structure and procedure with a self-referential strategy, to become a constituent unit for democratic community. In the next section, a model of EDP is suggested based on the NDS theory that has been discussed so far.

B. Suggesting a Complexity Model of EDP

Based on the introduction of parameters for EDP, this section suggests a model of EDP in terms of NDS theory, borrowing three elements of NDS. Attributes of these three parameters—attractors, bifurcations, and fractal structure—contribute to each phase of the decision-making process: initial phase, developmental phase, and recursive phase, respectively. Each parameter has its own variables, as it is explained above: attractors have fixed-point attractor, repellor, limit cycle, and strange attractor, which work as 'positioning factors' in the decision-making process. Bifurcations have bifurcation point, period doubling, control parameter, and order parameter, which act as 'influential factors.' Fractal structure has traits of self-reference, complexity, chaotic attractor, and Annihilation phase, which function as 'constituent factors.' These variables and their traits can be organized as shown in the following <Table 2>.

Table 2 Variables adopted for the NDS theory of EDP

NDS elements	Attractors	Bifurcations	Fractal structure
Decision process	Initial phase ►	Developmental phase ►	Recursive phase
Variables in each phase	Fixed point attractor	Bifurcation point	Self-reference
	Repellor	Period doubling	Complexity
	Limit cycle	Control parameter	Chaotic attractor
	Strange attractor	Order parameter	Annihilation force
Decision making factors	Positioning factors	Influential factors	Constituent factors

To brief the mechanism, EDP is influenced by several positioning factors. These represent the stances, situations, or interests voiced by agencies or members of the institutional system, such as school. The agencies play their roles in the initial phase of EDP while breaking the equilibrium of the current status and making it unstable. Then EDP comes across the bifurcation point, selects a path, and goes through the developmental phase of the decision-making process. During this phase, EDP is influenced by the impact of period-doubling, control- and order-parameters. At the same time, this process embodies some constituent factors like self-reference, complexity, or chaotic attractor, and finally falls into the Annihilative phase. In this last phase, the process might become intermingled or complicated and lose its direction; however, Chaotic attractors could break the stagnation and lead the process into a certain direction or a totally different horizon. These systematic and recurrent phases provoke complexity, diversity, and creativity in the system of NDS.

The typical application of Complexity theory to social science or human affairs is Organizational Development (Porras & Robertson, 1992), which can be termed as "a structured set of techniques for transforming an organization from one state of affairs to another." According to Guastello (1995), there are three significant assumptions in OD theory: i) the changing stage is initialized by the need for a change; ii) anything that appears frozen is "just a temporary respite between bouts of change, which are primarily chaotic"; iii) even where there is internal quietude, turbulence characterizes the external environment, which itself is a source of chaotic behavior within the organization (p. 336). The most important lesson from the OD theory is that, even though the development looks chaotic, we can control it. What we need is 'a need for change' to break through quietude. When you submit your final version, after your paper has been accepted, prepare it in two-column format, including

figures and tables. In short, to initiate a change, an organization needs to be moved to a bifurcation point that yields an unstable situation. From that point, change becomes possible. An organization moves to its bifurcation point when its internal entropy level has increased sufficiently. This mechanism of chaotic paradigm of OD implies that creativity induces chaos and chaos induces creativity. Chaos and creativity are thus parts of a reciprocal dynamic, and self-organizing process and communicative link assist the transition from chaos to a creative work. This paper calls it a Complexity model of EDP which can be illustrated as the following flowchart as [Figure 1].

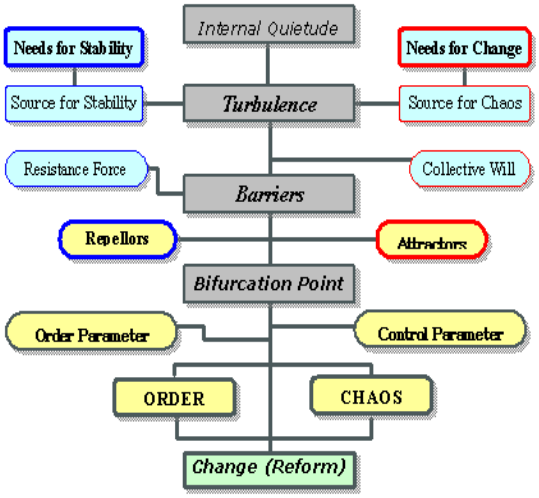

Figure 1 A Complexity model of EDP for democratic school change

This model visualizes how a change might happen in EDP in term of parameters and variables of Complexity theory. An initial stage starts from internal quietude; however, every institution has problems and defects that need to be reformed. Usually, the need for change comes from the grassroots who are suffering from the problems. Hence, needing work as sources of the seed of chaos, they make the system turn into a phase of turbulence. However, resistance that makes things remain in their status-quo emerges as a barrier against the change. At this point, several attractors or repellors may work as variables in the decision-making process. These attractors/repellors create conditions for a bifurcation point, and this point is also swayed by order/control parameters that make the phases of change complex/simple, fast/slow, or order/chaos. In a final phase, the process is still under the influence of known/unknown chaotic factors, which are themselves the source of creativity. This reciprocal loop of effects between creativity and chaos is the conclusive factor that finalizes the change. However, this newly-drawn change is never an end-result; in the system ruled by Complexity theory of NDS, new order always is a seed for new chaos.

IV. CASE ANALYSIS: APPLICATION OF COMPLEXITY MODEL

This paper applies this model to one real case of democratic school reform in La Escuela Fratney school (henceforth, Fratney school). This school has been introduced as one of the cases that a school policy decision made democratically, overcoming many conflicts among the school members (Apple & Beane, 1995).

A. Backgrounds of the school

Fratney (High) School in Milwaukee, U.S.A. was promoting a two-way bilingual, multicultural, whole-language program. It had 360 students from kindergarten to fifth grade; 65 percent of them are Hispanic, 20 percent African American, 13 percent white, and the remainder Asian and Native American. According to the author (Peterson, 1995: 60), Fratney School encountered five major problems in promoting the bilingual program: i.e., i) a central office wedded to autocratic methods of leadership; ii) a school system structured to inhibit collaborative teaching practices; iii) parents and teachers tied to the authoritarian habits of their own schooling; iv) students conditioned by a mass-media culture that values individual consumption over the common good; and v) a socioeconomic system that places little value on urban schools and the families served by them. These are the obstacles that the school board has to resolve, and here is how they reached an agreement and made a successful school change.

B. The process of reform

Facing the peril of demolition of the school, a reform was initiated by Neighbors for a New Fratney (NNF), which raised an agenda that the school would be run by a site-based council of parents and teachers, in opposition to what the administrators wanted: a teacher training school organized and run by the central office. Consequently, there had been struggles for political power and debates and conflicts over developing the program, including renovating the facility, selecting the principal and other staff, and putting in place the curriculum and related materials. The series of efforts by NNF to promote the new program can be listed as in the following <Table 3>:

Table 3 NNF's efforts and their relevancy to complexity parameters

The process of change of Fratney school	Parameters
I. Initial Status: The Collapse of old Fratney school → Needs for change 1) Parents' concern for their students 2) Announcement of NNF's vision and mobilization of the community	Collective Will for a change (Attractors)

II. Conflicts Efforts of Change (For a two-way bilingual school: A school run by a local teachers and parents)	Reluctance to Change (For an Exemplary Teaching Centre: A school for staff development)	(Turbulence) bt. Attractors and Repellors
III. Seed for change : A exemplary success story of a 1st grade student		Bifurcation point
IV. Efforts vs. Barriers 1) The effort of parent representatives 2) A nationwide search for a new principal 3) Efforts to get new material and resources	1) Stonewalling of the admin. 2) Puppet principal 3) Administrator's refusal of releasing school materials	-Control /Order parameters -Attractors met repellors:
A change happens in the critical moment 1) Stormed into the central office, and made the superintendents their allies 2) Change of attitude of Superintendent: Made the administrators in line 3) Finally, the tide had turned in climax, then Period-doubling has occurred		Chaotic attractors
Reform achieved		

The process of change of Fratney School can be analyzed into five stages: i) initial status wanting for change, ii) conflicts between efforts of change and reluctance to change, iii) emergence of seed for change as a bifurcation point, iv) a series of efforts of change vs. barriers against the change, and v) continuous efforts made the dramatic change in the critical moment and finally reform achieved. The analysis of the process yields the following six lessons.

C. The Analysis: Six lessons

Lesson 1: Grass-root movements can produce real change. Grass-roots movements at a class level were the initiating democratic seeds for a change against static, desperate, undemocratic situations. The initial grass-roots movement was a smaller scale fractal structure to make up a larger scale structure with its self-referential development.

Lesson 2: Multiracial unity is essential to successful school reform. The main points of this theme were: i) to make each group of people convinced about the reform; ii) to set up decision-making sub-groups; and iii) to try to institutionalize power relationships between majority and minority groups for the issue.

Lesson 3: Build in time to reflect and learn. This repetitious trial and recursive feedback on the system would have become a motivational power for reform. Those forces lead a system to the catastrophic and explosive bifurcation. In Fratney's case, three factors functioned as such explosive bifurcations: i) a collective will from teachers and students was organized; ii) ideas and suggestions reflected by members of each, and structured; and iii) the time and experience shared with each other were accumulated as period- doubling forces (or phases) for change.

Lesson 4: Genuine parent involvement is critical. The 'parent' variable can work either as attractor or repellor. Fratney's experience shows that parents are more likely to come to the school if they are able to exercise genuine power in decisions that directly affect the future of the school and their children's lives. Fratney school took full advantage of the 'parental' factor as an attractor in developing a democratic school.

Lesson 5: Structures that foster change must be institutionalized. The success of many schools is a result of many people spending enormous amounts of time and energy in a fight against the status quo. Therefore, people must institutionalize structures that allow and foster change in public schools and in the teaching profession.

Lesson 6: Successful school reform is part of larger efforts for societal change. Fratney experience has shown us that the reform of any particular school must take place within a larger context of district-wide curricular reform and structural change. Small efforts like La Fratney can be a foundation for the development of community-wide coalitions between parents and schools to enhance activities and movements that will improve schools and communities alike.

This attitude makes them live, healthy, and significant for all of the school members and their neighbors. This application of six lessons can be also portrayed in flowchart as in the following [Figure2].

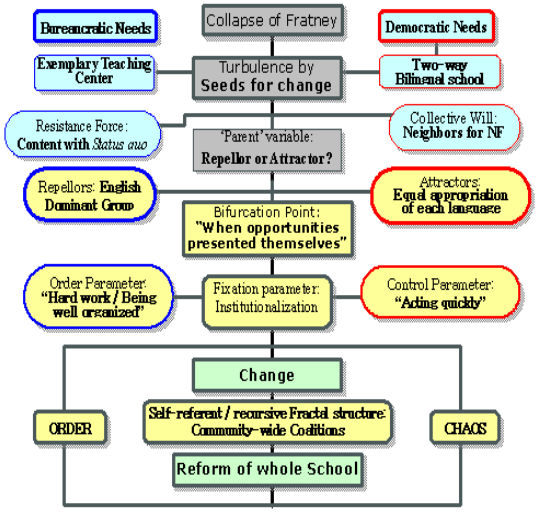

Figure 2 An application of Fratney school case to the Complexity model for Change

To review the flowchart, there were two choices to save the collapsing La Fratney school: an 'exemplary teaching center' initiated by bureaucratic needs, or a 'two-way bilingual school' to help real kids in need. Facing the collective will for democratic change, La Fratney school was about to change; however, there were repellors in the course of change, i.e. a resistent force seeking to keep thestatus quo, the 'parent' variables, skepticism, etc. Nonetheless, La Fratney school has made a successful change and has been reborn as a democratic two-way bilingual school.

D. Implication of the study

NDS theory gives us meaningful insight to understand and get prepared for the essential complexity of EDP for contemporary schools. There are three fundamental merits if we understand and incorporate the NDS variables in our discussion of EDP. First, it is sensitive to low-level stimuli. This means that we could be very sensitive to minor, low-level, and intermittent opinion, especially the opinions of students, minorities, and unprivileged people, which makes EDP democratic. Second, it is flexible. Multiple-functional systems that are chaotic are much more flexible, while a non-chaotic system is to be regulated by mono-functional controller. Considering chaotic factors in EDP makes the decision much more situational, adjustable, and reliable. It does not require 'one size fits all' adoption. Third, it summons up creative resolution. The circulation of chaotic variation is not a closed circuit. Chaotic system, essentially, is open to any change as it allows the system to become complex and look randomly. But within the randomness, there is a seed for creativity, change, variation, and progress. Our job is not blocking chaos, but allowing it in a controllable way for a desirable direction.

CONCLUSION

By revisiting the Complexity theory for NDS in terms of an application to social science, this paper has discussed several important concepts of the theory and tried to adapt them to EDP for democratic school. Among them, this paper chose three major elements of NDS theory: Attractors, Bifurcations, and Fractal structures, and analyzed EDP in the perspective of metaphoric notions of these parameters by extracting democratic methods or strategies embedded in the concepts. This paper has also proposed that several traits of such parameters can be applied to the appropriate stages of EDP, and explained them by suggesting a specific model, the Complexity model for Change. Finally, this paper has applied the model and its analysis to one real schools' case of democratic reform in Fratney School that was introduced in Peterson (1995).

Contrary to the perspectives of linear dynamic system theories, which simply posit contradiction and incompatibility between chaos and order, NDS theory acknowledges complementarity between the two, which says 'order is embedded in chaos.' A self-organizing dynamic force in a chaotic system (or open system) makes the circuit run incessantly: from Annihilation to Attractors, to Bifurcations (or Period-doubling), to Fractal structures (self-reference/ complexity), and again to Annihilation. This paper's application of this conceptual framework to EDP in school is significant because: i) it recognizes schools as complex, open, and organic institutions, which highlights the fact that schools are not static, stratified, or fossilized institution, but very lively, variable, and growing organizations; ii) the inducement of chaos theory sheds new light on EDP in school administration since it helps school leaders, including policy makers, administrators, teachers, and community representatives, to have more flexible, diverse, and creative perspectives on the EDP; and iii) it provides us an idea about what factors are influential for making a democratic school successfully: e.g. recognition of any chaotic movement in small scale, being sensitive to initial conditions, and attention to the voices from the grass roots (students, parents, and teachers).

REFERENCES

[1] Apple, M. W. & Beane, J. A. (Eds.). (1995). Democratic Schools. Alexandria, VI: Association for supervision and curriculum development.

[2] Ball, S. J. (2016). Education, justice and democracy: The struggle over ignorance and opportunity. In Reimagining the Purpose of Schools and Educational Organisations (pp. 189-205). Springer International Publishing.

[3] Barratt, W. (1994). A primer of non-linear dynamics. Contemporary Education, 66, 48-51.

[4] Bolman, L. G., & Deal, T. E. (2017). Reframing organizations: Artistry, choice, and leadership. New York: John Wiley & Sons.

[5] Bowe, R., Ball, S. J., & Gold, A. (2017). Reforming education and changing schools: Case studies in policy sociology (Vol. 10). London: Routledge.

[6] Brazer, S. D., & Keller, L. R. (2006). A conceptual framework for multiple stakeholder educational decision making. International Journal of Education Policy and Leadership, 1(3). [Online edition]

[7] Briggs, A. J. (1992). An efficient algorithm for one-step planar compliant motion planning with uncertainty. Algorithmica, 8(1-6), 195-208.

[8] Bruner, J. (1957/1973). Beyond the information given: Studies in the psychology of knowing. J. Anglin (Ed.), New York: W. W. Norton. (Original work published 1957)

[9] Cambell, A. B. (1993). Applied Chaos Theory: A paradigm for complexity. San Diego, CA: Academic Press.

[10] Davies, L. (2004). Conflict and Education: Complexity and Chaos. London: Routledge Falmer.

[11] Davis, B., & Sumara, D. (2006). Complexity and Education: Inquiries into Learning, Teaching and Research. Mahwah, NJ: Lawrence Erlbaum.

[12] Dimmock, C. (Ed.). (2013). School-based management and school effectiveness. London: Routledge.

[13] Fairman, J. C., & Mackenzie, S. V. (2015). How teacher leaders influence others and understand their leadership. International Journal of Leadership in Education, 18(1), 61-87.

[14] Furman, G. C., & Starratt, R. J. (2002). Leadership for democratic community in schools. Yearbook of the National Society for the Study of Education, 101(1), 105-133.

[15] Guastello, S. (1995). Chaos, Catastrophe, and Human Affairs: Applications of Nonlinear Dynamics to Work, Organizations, and Social Evolution. Mahwah, N.J.: Lawrence Erlbaum Associates.
[16] Habermas, J. (1987). The theory of communicative action: Life world and system: A critique of functionalist reason (Vol. 2). Boston: Beacon.
[17] Henderson, J. G., & Kesson, K. R. (2004). Curriculum wisdom educational decisions in democratic societies. Educational Philosophy and Theory, 42(2), 213-229.
[18] Hochschild, J., & Scovronick, N. (2000). The American Dream and the public schools. Informally published manuscript. Princeton, NJ: Princeton University.
[19] Hunter, W. J., & Benson, G. (1997). Arrows in time: the misapplication of chaos theory to education. Journal of Curriculum Studies, 29, 87-100.
[20] Kauffman, S. A. (1995). At Home in the Universe: the search for laws of complexity. Oxford: Oxford University Press.
[21] Macchia, P. Jr. (1994). Chaos theory and educational systems. Contemporary Education, 65, 211-214.
[22] Mandelbrot, B. B. (1983). The fractal geometry of nature. New York: Freeman.
[23] Maxcy, S. J. (1995). Democracy, chaos, and the new school order. Thousand Oaks, CA: Corwin.
[24] McKenzie, K. B., Christman, D. E., Hernandez, F., Fierro, E., Capper, C. A., Dantley, M., et al. (2008). From the field: A proposal for educating leaders for social justice. Educational administration quarterly, 44(1), 111-138.
[25] Merry, U. (1995). Coping with Uncertainty: Insights from the New Sciences of Chaos, Self-Organization, and Complexity. Westport, CN: Praeger Publishing.
[26] Morrison, K. (2002). School Leadership and Complexity Theory. London: Routledge Falmer.
[27] O'Hair, McLaughlin, & Reitzug (2000). Foundations of democratic education. Orlando, FL: Harcourt.
[28] Peterson, B. (1995). La Escuela Fratney: A Journey toward Democracy. In M. W. Apple, & J. A. Beane (Eds.), Democratic Schools (pp. 58-82). Alexandria, VI: Association for supervision and curriculum development.
[29] Poincaré, H. (1952). Mathematical discovery. Science and method, 46-63.
[30] Porras, J. I., & Robertson, P. J. (1992). Organizational development: Theory, practice, and research. Consulting Psychologists Press.
[31] Prigogine, I. (1984). Order out of chaos: Man's new dialogue with nature. New York: Bantam Books.
[32] Schoenfeld, A. H. (2010). How we think: A theory of goal-oriented decision making and its educational applications. London: Routledge.
[33] Winn, M. I., & Keller, L. R. (2001). A modeling methodology for multi-objective multi-stakeholder decisions: Implications for research. Journal of Management Inquiry, 10(2), 166-181.

★★★