Chapter 12
Understanding Chaos and Complexity in Education Systems Through Conceptualization of Fractal Properties

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Abstract Education is a trans-phenomenal, trans-disciplinary, and inter-discursive enterprise. Research into education necessarily reflects this. Educational theorists are making increasing use of the metaphors and concepts of complexity thinking in their discourses. This is normally done in company of exploration of chaotic tendencies in education systems. In this paper we discuss the elements of complexity that engulf educational systems today and highlight some cases of chaos in the education system as well. In doing so we also dissect the properties of fractals which obtain in chaos and complexity theory and how they relate with the features of education systems. We conclude by arguing that if the managers and stakeholders in education are fully abreast with properties of fractals, they would find education systems quite manageable since the properties would inform their operations through understanding the nature, steps and implications of various scenarios in the education system. Thus knowledge of fractal properties becomes a sine-qua-non for educational management and understanding of education systems.

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We hope the study is a ground breaking one and there is no gain saying that it will contribute massively to the growing body of elusive knowledge that is fractals and how they can help educationists transform the education systems.

Keywords Education · Chaos · Complexity · System · Fractals · Fractal properties

12.1 Introduction

The dawn of the 21st century has brought with it an unprecedented wave of change. The days of mass production or standardized products appear to be over. Accordingly, the key words for the future are variety, flexibility, and customization. These have ushered in a new order indeed. The new sciences of chaos and complexity and the study of non-linear, dynamic systems have helped Western scientists recognize this order in phenomena that were previously considered chaotic and random (Alexander 2011). The theory of complexity emphasizes that the relationships in the complex systems such as organizations are not linear, and have a structure revealing unexpected results and arising choices in which the events cannot be predicted (Erçetin et al. 2013). These patterns reveal new sets of relationships that point to the essential balances and diversity that help nature to thrive. Western scientists have constructed the holographic image, which lends itself to the Native concept of everything being connected. The relationship of each part to everything else must be understood to produce the whole image (Alexander 2011).

Moreover with fractal geometry, holographic images and the sciences of chaos and complexity, the Western thought-world has begun to focus more attention on relationships among elements rather than on elements in isolation. Thus there is a growing appreciation of the complementarity that exists between what were previously considered two disparate and irreconcilable systems of thought. There is a new way of thinking ad conceptualization of things around us as a result.

Among the qualities that are often identified as inherent strengths of indigenous knowledge systems are those that have also been identified as focal constructs in the study of the dynamics of complex adaptive systems. In addition to unpredictable behavior of complex adaptive systems systems in chaos, they have fractal patterns that symbolize strange attractors (Erçetin, 2001) According to Nanavati and McCulloch (2003), Michael McMaster, a management consultant who has applied the science of complex systems to management practices in organizations in Great Britain, indicates that “Complexity theory is about identity, relationships, communication, mutual interactions.” These qualities focus on the processes of interaction between the parts of a system, rather than the parts in isolation, and it is to those interactive processes that the AKRSI educational reform strategy has been directed (Barnhardt and Kawagley 2003). In so doing, however, attention must extend beyond the relationships of the parts within an indigenous knowledge system and take into account the relationships between the indigenous system as a whole and the external systems with which it interacts, the most critical and pervasive being the western formal education systems that now impact the lives of every native child, family, and community in the world (Nanavati and McCulloch 2003).

12.2 Chaos and Complexity in Education Systems

The dictionary Meaning of *Chaos* is "a state of things in which chance is supreme; especially: the confused unorganized state of primordial matter before the creation of distinct forms" (Webster).

Chaos Theory represents a big jump from the way we have thought in the past—a paradigm shift. The traditional notion of chaos is simply; unorganized, disorderly, random etc. But *Chaos theory* has nothing do with the traditional notion per se. On the contrary, it actually tells you that not all that 'chaos' you see is due to chance, or random or caused by unknown factors. Chaos theory is thus about the deterministic factors (non-linear relationships) that cause things to look random.

Rosenstein and Collins (1998) contend that since the early 1980s, the field of chaos has enjoyed a remarkable growth in popularity. With origins primarily in physics and mathematics, chaos has gained the attention of researchers from largely disparate disciplines (e.g., physiology, communications, and economics). Unfortunately, this popularity has not been free of undesired side effects. Some experimentalists, for instance, use the tools (i.e., numerical algorithms) of chaos without familiarity of their theoretical limitations.

Chaos has been a big part of education systems in various forms (Cahill 2010; Cunningham 2000). The three principal conditions for a chaotic system are: (1) that it operates in a non-linear way; (2) that it is iterative (the output of one cycle becomes the input of the next); and (3) that small variations in initial conditions lead to large differences in outcomes. Many systems within educational organizations appear to meet these conditions (Cunningham 2000 cited by Kara 2008). Accordingly, education is an essential component in responding to emergencies after conflicts or national disasters (Cahill 2010).

Suffice to say, when a complex adaptive system is portrayed as a learning system (whose components are humans) the move to educational contexts seems quite natural (Newell 2008). This application of complexity science and new concept of learning creates new ways of imagining and talking about educational processes. Mennin (2010) opines that education appears to be in a state of perpetual unrest. Indeed education currently exists in a state of tension between the tendency to fall back into traditional teacher-centered pedagogies and the urge to reach to newer, more interactive, authentic, integrative and transformative approaches to teaching and learning.

Along the same line, complexity in education systems is on the rise due to a number of intersecting trends (Hopper et al. 2013; Peurach 2011). Parents in OECD countries have become more diverse, individualistic and highly educated

(OECD 2013) and this pushes schools to cater for the individual needs of their children. How to transform under performing schools to higher performing ones (Peurach 2011) thus becomes a central theme of education. For this to happen though there is need to understand a number of complexities in the education system. These may include complexity of thinking, intervention and learning (Hopper et al. 2013).

Related to the above there are also uncertainties in education systems that make it complex. Indeed such uncertainties include; uncertainty in Teaching (Jackson 1986), uncertainties about instructional content (Schoön 1983), uncertainties about authority and influence (Lortie 1975), uncertainty about personal development and uncertainty about changes within learners (Clark and Floden 1988). Meanwhile large numbers of students in classes and schools, increasing diversity in student populations, student mobility, scarce resources, pressure on accountability, competition for good students (Bourgeois 2002) are other forms of complexities that obtain in the education systems today and which the educational managers as well as other stakeholders have to contend with on a regular basis. Mennin (2010) postulates that the school as a whole and the expression of its curriculum through the interactions, exchanges and learning that take place within and outside of the school is a complex system.

At the same time, ministries of education remain responsible for ensuring high quality, efficient, equitable and innovative education. Therefore, one of the crucial questions for OECD countries is how their increasingly complex education systems can achieve national objectives (OECD 2013). Education systems revolve around teamwork, participation, and learning. They also revolve around improved communication, integration, collaboration, and closer interaction and partnering with customers, suppliers and a wider range of stakeholders. Value creation, quality, responsiveness, agility, innovation, integration and teaming are increasingly regarded as useful guiding principles in the evolving new environment.

Credaro (2006) states that internal to the school are the pressures brought to bear by curricular reform. Further, alterations in staff-student relationships from teacher-centred to student-centred create the need for modification of teaching practices, and policies and procedures to support more meaningful educational experiences (Dean 2000). In keeping with Credaro (2006) educational institutions themselves, must restructure the framework of their organization to form learning communities rather than institutions whose core function is the dispensing of information. The innovations and changes are at system, whole school and classroom level.

Iancu et al. (2012) identify two key aspects: the paradigm of learning environments and learning activities and the paradigm of instructional resources which are not only institutional, but also affecting the time and energy of students. Equally Neave (1998) cited by Georgeta and Castro (2012:337) argues that the general acceptance of this paradigm shift has been accompanied by the introduction of new assessment procedures and models of accountability in school systems. Newell (2008) tries to make a connection between complexity science and education by bringing in the classroom picture. He draws on a number of conditions that underpin this similarity. The conditions are (a) internal diversity, (b) redundancy, (c) decentralized control, (d) organized randomness, and (e) neighbour interactions.

Internal diversity is closely linked with a system's creativity or intelligence. The insight that a group's potential for varied response increases with the sum total of the individual capabilities within the group is not unique to complexity science. But complexity science accentuates that such diversity is a blessing in disguise for a collective intelligence (Newell 2008). In a complex system, however, it is not the existence of diverse talents among its agents, but the appropriate interaction of such talents that gives rise to adaptive behaviors that transcend those of the system's individuals. Meanwhile, diversity in a class determines how well it will respond to the external environment (such as, for example, the curriculum). Redundancy in a class is key to establishing coherence. External flexibility is kept in balance with internal robustness.

Generally therefore, a number of aspects render the education system rather complex and a summary of some is drawn from a multiplicity of researchers to the following effect (McManus 1993; Dean 2000; Pintrich 2000; Lemke and Sabelli 2002):

- Integrating the commonly polarized goals of education, that is the goals that focus on transmitting knowledge with the goals that emphasize the development of an individual in the system.
- Catering for individual student needs. Running a classroom which recognizes and respects difference is first in the hands of a teacher who acknowledges that there are differences in the classroom.
- Assessment feedback and learning approach. We might consider the role of high-stakes standardized testing and assessment schemes in the present educational system as imposing an artificial fitness landscape that pulls the system toward behaviors that maximize test results rather than deep conceptual understanding.
- The dynamic nature of education system, the teaching and learning system that exists within the education system is subject to change with the changing world. Innovations and inventions must be incorporated into the system with the aim of maximizing student performance.
- The existing educational system of schooling isolates students and teachers from the wider community.
- Integrating the curriculum by developing interdisciplinary curriculum units that enable students to acquire knowledge from disciplines through unifying them while having the opportunity to contribute in different and special ways to the objectives of the integrated units.
- Dealing with misbehavior is a complex undertaking. Student misbehavior in the classroom is a tough and unavoidable task to the teachers and it takes up teachers' considerable time to deal with, which in turn affects the quality of the student's learning experiences.

Education systems are now characterized by multi-level governance where the links between multiple actors operating at different levels are to a certain extent fluid and open to negotiation (Burns and Wilkoszewski 2011), also they propose pondering over the following questions:

1. What models of governance are effective in complex education systems?
2. What knowledge system is necessary to support the effective governance of complex education systems?

Answers to such complex questions bordering on education can only be found in more complex systems and theories indeed. A closer look at *fractal properties* would reveal that they would go a long way in helping educationists understand and conceptualize the chaotic and complex terrain of education in the contemporary times. As always claimed in chaos theory and fractals, within the seemingly chaotic, disorganized and complex systems is a certain level of organization and orderliness that can serve as a basis of turning educational complexity into opportunity.

12.3 Description of Fractals

> 'The rationality of our universe is best suggested by the fact that we can discover more about it from any starting point, as if it were a fabric that will unravel from any thread.
> George Zebrowski (1994 cited by Pickover 1998).

The earliest works on fractals can be traced from Mandelbrot and Edward Lorenz (Gleick 1987). In general Benoit Mandelbrot is credited with advancing Fractals and Edward Lorenz with formalizing Chaos theory in Modern times. However, Fractals have of recent attracted the attention of many researchers and scholars alike (Snyder 1995; Glickman 2001 cited by Kara 2008). All these have endeavored to explore the nature of fractals in both the natural and scientific systems (Glickman 2001 cited in Kara 2008). The claim therefore is that Fractals are not just complex shapes and pretty pictures generated by computers. Anything that appears random and irregular can be a fractal (Fryer and Ruis 2004). Fractals permeate our lives, appearing in places as tiny as the membrane of a cell and as majestic as the solar system (Kara 2008). Fractals are the unique, irregular patterns left behind by the unpredictable movements of the chaotic world at work.

Kluge (2000), writes that in theory, one can argue that everything existent on this world is a fractal: the branching of tracheal tubes, the leaves in trees, the veins in a hand, water swirling and twisting out of a tap, a puffy cumulus cloud, tiny oxygen molecule, or the DNA molecule and the stock market.

The definition of Fractals has always challenged many, a researcher and scholar. Fryer and Ruis (2004) contend that the word "fractal" often has different connotations for laypeople than mathematicians, where the layperson is more likely to be familiar with fractal art than a mathematical conception. It is imperative to note that Fractals have always been associated with the term chaos (Gleick 1987). One author elegantly describes fractals as "the patterns of chaos". Fractals depict chaotic behaviour, yet if one looks closely enough, it is always possible to spot glimpses of self-similarity within a fractal.

To many chaologists, the study of chaos and fractals is more than just a new field in science that unifies mathematics, theoretical physics, art, and computer science—it is a revolution. It is the discovery of a new geometry, one that describes the boundless universe we live in; one that is in constant motion, not as static images in textbooks. Today, many scientists are trying to find applications for fractal geometry, from predicting stock market prices to making new discoveries in theoretical physics.

The application of fractals has also not gone unnoticed. From people of ancient civilizations to the makers of Star Trek II: The Wrath of Khan, scientists, mathematicians and artists alike have been captivated by fractals and have utilized them in their work. It is thus argued that Fractals have more and more applications in science (Glickman 2001 cited by Kara 2008). The main reason is that they very often describe the real world better than traditional mathematics and physics.

Astronomy, medicine, surface physics, telecommunications, fluid mechanics, computer science and nature are perhaps the most critical areas where fractals are dully represented. According to Sprott (1998), all of these fields benefit because fractal geometry provides a language and conceptual framework for ill-defined geometries, and the power law inherent in fractals condenses their description. For example, fractals will be increasingly used to estimate the strength of rocks under shearing forces, in the analysis of breast mammograms, and in analyzing the randomness of transcendental numbers.

Meanwhile Klein and Rossler (1998) argue that "Chaos" and "fractals" seem to bridge the gap between physics and philosophy, mathematics and nature, and computer and art. The *Fractal Geometry of Nature* [B.B. Mandelbrot, 1982], *Fractals Everywhere* [M.F. Bamsley 1988], *The Beauty of Fractals* [H.O. Peitgen and P.H. Richter 1986], or *Does God Play Dice?* [I. Stewart, 1989] are only some of the very promising book titles exploring fractals at their intricate best. One reason for the success of *Chaos: Making a New science* (Gleick 1987) is the fact that it deals with a classical theory.

Nevertheless, the view is that fractals have also found their way into social sciences, arts and humanities (Kara 2008). Accordingly scholars and researchers have examined fractals in areas like management (Credaro 2006; Carnall 2003; Greenwald 2001 cited by Jamali 2004), administration (Garmston and Wellman 1995; Herghiligiu et al. 2013), organizations (Sandkuhl and Kirikova 2011; Mrówka and Mikołaj 2011), leadership (Raye 2012; Nonakaa et al. 2013; Topper and Lagadec 2013), business systems (Yan-zhong 2005).

Imperative to note is that there has been limited attention paid to Fractals in the field of education (Kara 2008; Barnhardt and Kawagley 2003; Nanavati and McCulloch 2003; Alexander 2011). The few studies that can be traced mainly deal with chaos and complexity in education systems thereby rendering a view on fractals (Lortie 1975; Cunningham 2000). The most specific attachment to fractals in education features teaching and learning processes (Claypole 2011) as well as chaos and complexity in the classroom (Trygestad 1997; Newell 2008).

However all these studies do not capture the relationship between fractals (especially fractal properties) and the seemingly chaotic and complex education systems. The study in question therefore comes in handy to describe how knowledge of fractal properties aids educational managers, educationists as well as other key stakeholders to understand the nature of education systems whilst helping to turn the seemingly educational chaos and complexity into opportunity.

12.4 Reflection of Educational Chaos and Complexity in Fractal Properties

School managers and all stakeholders ought to know that contemporary education systems are premised on nonlinearity. In a linear system there is a simple cause and effect relationship; A causes B which causes C, and so on. However, a chaotic system is nonlinear. A may not necessarily cause B at all times. Lots of variables come into play and interact with each other. School systems look like nonlinear chaotic systems, too. In school district A, the purchase of new computers might have a positive impact on student achievement, while in school district B, this might bring little or no gain in student achievement.

Kara (2008) indeed postulates that it is widely believed that experienced teachers have better classroom control. If you have a veteran teacher in a classroom, you will have an orderly environment and the administrators, thinking in a linear way, might believe that the more veteran teachers in a building, the more orderly the environment will be. That might not be the case in every school district, especially in urban schools; there are instances where young and inexperienced teachers contribute positively to the school environment much more than veteran teachers.

It is imperative to note that the whole idea of educational systems reflected within learning processes, teaching strategies, administration, relationships between stakeholders, resources etc. and the complexity there in can easily be understood once *fractal properties* are conceptualized. Fractals are home to a number of characteristics, herein coined as properties that distinguish them from other features. Yan-zhong (2005) while reflecting on the major characteristics of fractal organization pointed out the following:

Self-similarity: The self-similarity of fractal administrative organization includes self-similarity of administrative organization structure and that of function, i.e. the function of a small fractal unit can be in harmony with that of the large one.

Like fractals in nature, schools reveal self-similarity in different scales. For example, a school-wide staff development day, a department meeting, a classroom lesson, and a halfway interaction between a teacher and student might all reveal the same cultural characteristic. Thus, reflective inquiry at the school, team, classroom and individual level can help educators better understand their school culture, change needed, and pathways to improvement (Glickman 2001 cited by Kara 2008). Even basic learning themes and aspects of discussion in meetings found on different agendas in schools are quite generative. They actually are the same but taught differently or discussed differently at various levels (Teichler 2002).

Iteration: Large amounts of fractal geometry examples are the figures produced by mathematical methods, especially by iteration and recursion arithmetic. The symmetry of different scale of fractal self-similarity means the iteration and recursion of pattern: pattern nesting in patterns, subdivision created on more and more detailed scaling, forming infinite delicate structure.

In education systems teachers help students to learn by designing curricula and learning experiences that are contextually rich, recursive and relational (Teichler 2002). The implication thereto is that even without the teacher learners can survive by learning on their own.

Self-organization: This is the remarkable character of system internal structure with fractal feature, in different scale, whose structure has the feature of self-similarity and self-copy, appear to be a new structure on macro-scale under open system through systemic cooperation, i.e. external environment only provides some conditions but does not carry out any specific intervention and it is formed by the system itself.

In terms of education systems, teachers, learners, planners all promote conditions for self-organization (integration) through dialogue, stories, problems, unresolved situations, questions and incomplete undertakings; all of which serve to disturb the status-quo and stimulate curiosity, interaction and exchange (Mennin 2010). This interaction and exchange is always the basis of transformation of the system at different levels and varying places.

Dynamic process: Fractal means a series of dynamic processes which reflect the growth and evolution of structure. It portrays not only the still form but also the important evolutional mechanism of dynamics.

It is largely known that from general to specific learning and teaching structures, education is home to dynamic processes and structures at all levels (Fischer and Immordino-Yang 2002). These may include Quantitative versus qualitative structures, centralized versus decentralized structures, mono-disciplinary versus multi-disciplinary structures, levels of education: bachelors, masters, and doctorate, gender structures etc. and understanding this *fractal property* helps educationists conceptualize dynamism in education systems effectively.

Simple regularization in complexity: Along with economic development, social progress and societal rising hierarchy, people's needs and requirement become more and more complex, this follows that administrative management becomes more and more complex.

New research in education suggests that children who learn to mind their Ps and Qs may also have an easier time learning their ABC's and 123's. There is also a lot of focus on good self-regulation skills in schools so that learners have better relationships with teachers, classmates and other school personnel (Hoffman 2010). The implication here is that when learners are self-regulated they help the system perform effectively, yet to understand this, educationists ought to be abreast with the knowledge of *fractal properties*.

Emergence: Rather than being planned or controlled the agents in the system interact in apparently random ways. From all these interactions patterns emerge which informs the behavior of the agents within the system and the behavior of the system itself. For example a termite hill is a wondrous piece of architecture with a maze of interconnecting passages, large caverns, ventilation tunnels and much more. Yet there is no grand plan, the hill just emerges as a result of the termites following a few simple local rules.

When subjected to education we realize that a proposal for a new curriculum in the school is an emergent pattern. It depends on what came just before and at the same time influences what will come next (Dean 2000). Once educationists grasp the concept of *fractal properties*, they easily get to understand how various patterns in the education system emerge and thus look at them from a realistic, anticipative and positive perspective.

Co-evolution: All systems exist within their own environment and they are also part of that environment. Therefore, as their environment changes they need to change to ensure best fit. But because they are part of their environment, when they change, they change their environment, and as it has changed they need to change again, and so it goes on as a constant process (Perhaps it should have been Darwin's "Theory of Co-evolution").

Some people draw a distinction between complex adaptive systems and complex evolving systems. Where the former continuously adapt to the changes around them but do not learn from the process. And where the latter learn and evolve from each change enabling them to influence their environment, better predict likely changes in the future, and prepare for them accordingly (Fryer and Ruis 2004). Fractal systems therefore, are as well adaptive as evolving.

Even in education systems teaching, learning and assessment become co-evolutionary events. This is because learning is understood as trans-active and transformative. Without one aspect in the school system, the others might not perform to the expected levels (Mennin 2010). To know this however, educationists may require the basic knowledge of *fractal properties*.

Sub-optimal: A fractal system does not have to be perfect in order for it to thrive within its environment. It only has to be slightly better than its competitors and any energy used on being better than that is wasted energy. A fractal system once it has reached the state of being good enough will trade off increased efficiency every time in favor of greater effectiveness.

Realistically, stakeholders in a school create discrepancies between what is and what could or will be. These lead to gradients and gaps in information and understanding among stakeholders which result in a need to know and act (Hoffman 2010). This leads to reflections and feedback which make the system more effective. Educationists who command knowledge of *fractal properties* would easily know that certain discrepancies in the education system may serve for the best when it comes to transforming the system yet on the other hand they learn that perfection is just but part of success.

Requisite Variety: The greater the variety within the system the stronger it is. In fact ambiguity and paradox abound in fractal systems which use contradictions to create new possibilities to co-evolve with their environment. Democracy is a good example in that its strength is derived from its tolerance and even insistence in a variety of political perspectives.

We note that in the education system a school committee like other complex adaptive systems will learn from its experience and adapt to changing circumstances as it pursues its task over time (Mennin 2010). The knowledge from *fractal properties* would help realize that variety is a positive and desirable thing in a school system since it widens the spectrum of learning and experiences.

Connectivity: The ways in which the agents in a system connect and interact to one another is critical to the survival of the system, because it is from these connections that the patterns are formed and the feedback disseminated. The relationships between the agents are generally more important than the agents themselves.

In education systems, the learning process is all about relationships between things. Creative play, interaction and exploration all bring about connectivity in the school system. Even as a group of teachers start working together they experience multiple interactions (Mennin 2010). Whereas the educationists may be scared of teachers' groups that may not be the case if they were abreast with knowledge of *fractal properties*.

Simple Rules: Fractal systems are not complicated. The emerging patterns may have a rich variety, but like a kaleidoscope the rules governing the function of the system are quite simple. A classic example is that all the water systems in the world, all the streams, rivers, lakes, oceans, waterfalls, etc. with their infinite beauty, power and variety are governed by the simple principle that water finds its own level.

Everyone in the school knows the aims, goals, objectives, mission, vision, strategies etc. these are reflected in well outlined documents in the school and always communicated via school functions, assemblies, parades, meetings, convocations to all stakeholders by those charged with administration or management of school affairs (Dean 2000; Hoffman 2010). In that case *fractal properties* inform us that the education system ought not to be complicated but simple for everyone to grasp.

Edge of Chaos: The edge of chaos is somewhere between order and disorder or between a chaotic and complex situation. According to chaos-complexity theory, this is the best scenario for an organisation or policy system because there is a higher degree of "creativity and innovativeness" hence the term "thriving on the edge of chaos" (Praught 2004).

Fractal theory is not the same as chaos theory, which is derived from mathematics. But chaos does have a place in fractal theory in that systems exist on a spectrum ranging from equilibrium to chaos. A system in equilibrium does not have the internal dynamics to enable it to respond to its environment and will slowly (or quickly) die. A system in chaos ceases to function as a system (Cloete 2004). The most productive state to be in is at the edge of chaos where there is maximum variety and creativity, leading to new possibilities.

In the education system, interactions among school employees initially serve to destabilize the group and move it through a variety of possible patterns or states until its members re-organize themselves and a shared understanding emerges in the form of a group decision about learning objectives or an agreed upon action or explanation (Mennin 2010). Knowledge of *fractal properties* implies that when the education system seems to be embroiled in chaos, it develops mechanisms of engaging the chaos which ultimately helps in getting out of the complexity thereby transforming for the better.

Nested Systems: Most systems are nested within other systems and many systems are systems of smaller systems. If we take the example in self-organizing above and consider a food shop. The shop is itself a system with its staff, customers, suppliers, and neighbours. It also belongs the food system of that town and the larger food system of that country. It belongs to the retail system locally and nationally and the economy system locally and nationally, and probably many more. Therefore it is part of many different systems most of which are themselves part of other systems.

In the education system, each person on a school committee is also a member of other complex systems that are nested within the other at different levels of interaction such as departments nested within the school, school with the community and individuals with social groups outside the school e.g. families (Teichler 2002). Knowledge of *fractal properties* would thus help educationists realize that the survival of the system is premised on the various interactions between members belonging to varying systems in the same bigger and larger system (Table 12.1).

Table 12.1 Reflection of fractal properties within education systems

Fractal property	Reflection within education systems
Self-similarity	Administration, departments, student bodies, classroom leaders, peer groups etc
Self-organization	Problem solving sessions, decision making processes etc
Dynamic process	Inequalities among schools, changing standards, centralized and decentralized systems, day and boarding systems etc
Simple regularization in complexity	Decisions taken at various levels in the school are always different
Emergence	Peer groups, pressure groups, student associations, teachers' bodies, disgruntled staff etc
Co-evolution	Stakeholders, local people, local institutions like mosques and churches, other schools etc
Sub-optimal	Less resources, moderate buildings, moderate learners, moderate teachers, moderate principals etc
Requisite variety	Power variety, character of people, opinions and views, variety of programs, various activities etc
Connectivity	Relationships, associations etc
Simple rules	Everyone in the school knows the aims, goals, objectives, mission, vision, strategies etc
Edge of chaos	Learners who are about to fail, teachers about to quit the school, principals pending firing, resources about to be finished, committees breaking up etc
Nested systems	A learner, peer group, classroom, department, school, region, ministry, government, country etc

Owing to the reflections in Table 4.1, whereas a simple look at the educational system may bring about a feeling of daunting chaos and complexity thereof, conceptualization of *fractal properties* would help educationists and other stakeholders know that such elements of chaos and complex are actually positive ones that can help in transformation of the education system. This would be a turn of educational chaos and complexity into opportunity indeed.

12.5 Conclusions

The deterministic view of education that schools are simplistic, cause-effect systems which can be easily manipulated, quantized and controlled is not addressing the problems of today's schools. From an alternative perspective, chaos theory gives us an understanding that the things we consider unimportant or trivial in our daily lives might have an equal weight in terms of affecting the results as the things we consider important. The complex education system is coming to look less familiar to us as the details unfold. We are conditioned to think of control, power, and authorship of knowledge as situated in individuals or groups of individuals. Final authority for what constitutes suitable truths for a class might be a curriculum, a text, or a teacher.

As discussed above therefore, education is a dynamic and complex system that evolves to meet the demands of society, the market and the educational institutions including schools themselves. Thus to be effective at education and learning the system must be designed to be agile and support changes. However, there is nothing that would come closer to improving our understanding and transformation of this complexity in education than a conceptualization of *fractal properties*. What this study has brought to the fore is that fact that chaos and complexity in education systems can easily be understood and turned into opportunity with command of knowledge of *fractal properties* by all educationists and stakeholders. This makes *fractal properties* a sine-qua-non for education.

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