

## ***Complexity and Systems Theory: Implications for the EFL Teacher/Researcher***

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Applied Linguistics has, since its beginning, attempted to employ principles and methods of research used more effectively and successfully by the physical sciences. Collection and analysis of language learning data has thus taken a Newtonian, cause-and-effect perspective, relying on isolation of factors, purity of experimental conditions and rigorous, quantitative interpretation. During the twentieth century, however, the “hard” sciences which had given birth to this view of the universe found it to be incomplete, and turned to more holistic ways of investigating time/space, weather, plant cell growth, and other phenomena which cannot be described or predicted in any but probabilistic terms. Complexity theory and systems theory are two examples of this new way of viewing data. Both are universally accepted in physical and social sciences, but have yet to be generally accepted in the field of language learning, largely because of difficulties associated with the identification and analysis of data. This paper examines some of these problems, and identifies some implications of systems and complexity theories for ELT teachers and-researchers.

Research into second language acquisition (SLA) and associated teaching methodologies has, during its history, shown a significant tendency to take its models from the physical sciences. Hence, approaches such as behaviorism, in the early part of the 20<sup>th</sup> century, were based on a cause-and-effect view of the universe (epitomized by the physical disciplines of mechanics and

engineering) that was particularly successful during the European industrial revolution. Language learning was thus seen as linear, predictable and subject to definable rules and conditions. According to this view, research into language learning should be detailed and rigorous, using an experimental mode of investigation, in which causative factors were to be identified and examined in isolation. The audiolingual approach of the 1960s and '70s continued to view SLA "scientifically," and even the notional-functional approach which followed (and which still lives on in many EFL textbooks) exhibited a behaviorist perspective in its attention to memorization of situational phraseology and vocabulary.

During the 20<sup>th</sup> century, however, disciplines such as Physics, Chemistry and Biology, faced with the inability to solve even the three body problem (explaining "the equations of motion for more than two objects moving under mutual influence," Laszlo, 2002, p. 4), and incapable of describing phenomena more complex than the helium atom (*ibid*), discarded propositional, isolationist research models as inadequate, replacing them with concepts such as complexity theory, model theory, string theory and systems theory. If SLA researchers wish to continue emulating the methods of the "hard" sciences, therefore, it is necessary to do the same – to reject the experimental model in favor of others which investigate complex, dynamic systems in combination.

Signs of dissatisfaction with the isolationist approach were apparent in L2 research in the latter part of the 20<sup>th</sup> century, giving rise to the qualitative mode of investigation, in which interviews, questionnaires, journals, and other subjective means of investigation are employed as valid and reliable research instruments. Along with the propositional/process "paradigm shift" (Breen, 1987) of the 1980's, and the acknowledgement of the importance of affect in the 1990's (Arnold, 1999), research into English language teaching (ELT) has already undergone a number of perceptual changes:

1. the process syllabus (including task-based language teaching [TBLT]) and the communicative approach to teaching have become recognized;
2. autonomy and affect have become crucial concepts in the ELT learning

- environment, along with authenticity and learner-centredness;
3. factors considered important for learning a language are no longer confined to linguistic categories, but have grown to include the distinctions between active/passive, teacher-centred/learner-centred, and authentic/non-authentic;
  4. sociolinguistics and psycholinguistics have grown in importance as ways of examining and explaining the learning process.

Language learning is now acknowledged to be a highly complex and dynamic process, driven by affect (confidence, motivation, attitudes, anxiety) and teacher(T)/student(S) perceptions. In this situation, the Newtonian view of causative reality, which was extremely effective in fulfilling the industrial requirements of 19<sup>th</sup> century Europe, is insufficient for the purposes of 21<sup>st</sup> century research into second-language learning. As Byrne (1998, p. 1) points out, the very nature of social sciences “has been tricky territory for scientific investigation, precisely because it is complex.” He goes on to warn about the danger of applying a “reductionist, positivist, linear and individualized, statistical approach to education,” stating that “there is a serious risk of [them] getting very important things seriously wrong” (Byrne, 1998, p. 9).

This paper suggests that systems theory and complexity theory offer a means of building on recent advances and of helping teachers and researchers to comprehend processes and phenomena in the learning environment. When examining the classroom (for example), with a view to assessing its effectiveness in the promotion of meaningful learning, it is useful to look at it from a holistic, systems perspective, and to see all the participants (T, Ss) as individual systems, each subject to their own influences and dependencies. From this viewpoint, each learner is an independent, many-faceted system, developing and changing through contact with other systems (parents, classmates, friends, TV, computer games, internet sites, movies, religion), and demonstrating a unique collection of needs, intelligences, learning preferences, learning styles, beliefs, perceptions and attitudes. The teacher is also a system of wants, needs, past experiences, social skills, professional skills and emotions (affective factors), and the interactions (connectivities)

between these systems, within the larger system of the classroom, is probability-based, being non-predictable at the local level, and leading to the emergence of learning structures, which are not simply the sum of their constituent parts. Taking this approach further, we find that the classroom is part of the school system, and that the teacher is the interface between this higher-order system and his/her pupils. Finally, the school is a subsystem of the education system, with the school principal interfacing between ministerial demands and teaching practicalities.

It is interesting to note at this point that “interaction,” as a statistical concept, “is what happens in applications of the general linear model when the effects of multiple variables are non-additive” (Byrne, 1998, p. 2). The use of the term in the language classroom would seem to refer only to verbal exchanges between participants, but if we extend this to include the affective and social systems of those participants, we can see that such verbal interactions are in fact the result of multiple variables, and that the whole (the outcome of those interactions) is greater than the sum of its parts. As Marsh states, interactions are “something that is a headache from a technical point of view but most exciting from the standpoint of substantive sociology” (Marsh, 1982, pp. 92-93). Seen from this perspective, the number of factors influencing or impeding the promotion of learning (cf. previous paragraph) is astronomic. However, we have yet to consider other aspects of the overall learning environment: school location; classroom location within the school; arrangement of desks in the classroom; number of students in the classroom; heating and air-conditioning; school rules (including uniforms); textbooks; assessment (type, frequency); teaching resources; electrical equipment; T/T/S/S relationships; etc. (Dörnyei & Murphey, 2003, p. 74). As we continue the search for factors influencing learning, it becomes apparent that every learning environment is different, that no two groups of learners are the same, and that any attempt to generalize in describing the learning process quickly takes on the nature of a game of Go.<sup>1</sup> This oriental board game has

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<sup>1</sup> An game played on a board with 19x19 lines. “Go” is the Japanese name, Baduk (바둑) the Korean name, and Wei-chi (碁) the Chinese name.

few rules, but (unlike Chess) is yet to be played at Master level by computer programs. In this game, played on a board with 19x19 lines and 361 intersections, the possibilities of choice for each subsequent move increase exponentially and it soon becomes impractical even for the most sophisticated computer to analyse those possibilities. In similar vein, the language learning classroom is a complex and dynamic system, in which the most influential factors are the connectivities (interactions) that occur between the participants. In order to research this system (and thereby to suggest strategies for effective teaching and learning) the sub-systems, their inter-relationships, and the new (unpredictable) structures which self-emerge from these, need to be observed in their entirety, rather than in isolation. This paper therefore examines how the EFL classroom might be satisfactorily and sufficiently described in the light of complexity and systems theory.

## **COMPLEXITY**

This section explores some key concepts of complexity and systems theory and examines their relevance to language learning. Readers interested in reading more about the concepts considered here are referred to the excellent expositions of Waldrop (1992), Larsen-Freeman (1997), Byrne (1998) and Laszlo (2002).

### **Open Systems**

The second law of thermodynamics (i.e., systems proceed from order to disorder; all matter tends towards entropy) provides a cosmic prediction of existing inequalities or concentrations of energy gradually evening out and settling into uneventful dissipation. However, it is important to note that this law applies to closed systems, in which there is no input or output. The language classroom and its participants are, in contrast, open systems; they receive continuous input (linguistic, affective, social), and they produce

continuous output. Any tendency to atrophy is balanced by these processes, which stir up the learning environment and keep the classroom in a state of creative complexity. It is precisely the openness of all these interacting systems that makes it impractical to test linguistic proficiency, since negative input in any of the areas (e.g., a death in the family, a car crash, the breaking up of a relationship) can have a significant detrimental effect on attitudes and language performance.

### **Connectivity**

A basic characteristic of complex systems is that everything influences and is influenced by everything else. These mutually influential relationships are called “connectivities.” Complex systems cannot exist in isolation, but affect each other in a multitude of ways. In terms of the language classroom, everything that occurs there impacts on everything else. The teacher’s use of competition as a motivator is an example of this concept. Telling students that “the first group to finish is the winner” immediately implies that the other groups are losers, and that speed of acquisition or performance is an important criteria of language learning. Students place importance on winning, rather than on quality of work, and interactions between students and groups change correspondingly. At the end of the activity, everyone (including the “winners”) ceases work, since the goal of being first has been achieved by some of them (Kohn, 1992, p. 47). The connectivities between participants in this event include teacher definition of valuable goals, student acceptance of those definitions and attempts to match them, labeling of success and failure, and extrinsic motivation. Instead of collaborating in a common goal of language learning, students withhold information from each other in a bid to achieve teacher-recognition, and groups are pitted against each other, despite the facts that “Those who believe they will lose may see little point in trying hard” (Kohn, 1992, p. 56) and “Research in non-recreational settings shows that those who are not successful in initial competitions continue to perform poorly, thereby setting up a vicious cycle”

(Johnson & Johnson, 1974, p. 224; cf. Holt, 1982).

An associated concept is the butterfly effect. The analogy of a butterfly in the West Indies flapping its wings and causing a typhoon in Hong Kong, is meant to demonstrate that minor connectivities in one location can contribute to exponentially increasing connectivities elsewhere, eventually causing major repercussions. Just as the uncertainties before the Gulf War affected stock markets and the lives of people throughout the world, so it is that unnoticeable or insignificant events in the classroom can have large outcomes in terms of attitudes to learning: "... very small differences in the values of control parameters ... determine which of two radically different trajectories the system settles into" (Byrne, 1998, p. 40).

### **Nonreducibility**

A complex, dynamic system (such as a classroom or a language) cannot be understood by reducing it to its parts. This is a significant finding for applied linguists and language teachers, since it means that target language cannot be fully acquired by studying it in parts, whereas the practice for so long has been to divide the target language into components (grammar, syntax, morphology, pronunciation, etc.) and to teach these in isolation, on the assumption that the student will somehow put them all together to form language (cf. Harris, 1997, p. 13; Miller & Ng, 1996, p. 134):

Even if we could identify and measure all of the factors in second language acquisition, complexity theory tells us that we would still be unable to predict the outcome of their combination. (Larsen-Freeman, 1997, p. 157)

Not only is there a large difference between knowledge of linguistic components and linguistic fluency, but the ability to use socially appropriate utterances (pragmatics) is also something that cannot be studied in isolation, though it is crucial to acceptable language use. Such proficiencies must be acquired and developed in the situations in which they occur, and in the context of holistic language learning.

## **Emergent Behavior**

Complex systems often show surprising and unexpected behaviors that appear to be a property of the system as a whole, rather than of its components. Flocks of birds and shoals of fish are examples of this concept. In isolation, birds and fish move around as they wish, but when in a large group of birds/fish, they somehow manage to act as if in one system, seemingly knowing when the whole flock/shoal is going to turn in any particular direction. This “emergent behavior” appears as a result of the connectivities (interactions) of the individual animals, and is a property of the whole system. Applied to the subject of this paper, it has been observed that the group dynamics of the language class differs from the characteristics of its participants:

Groups have been found to have a life of their own – that is, individuals in groups behave differently from the way they do outside the group. (Dörnyei & Murphey, 2003, p. 3)

In terms of the learning that occurs in the classroom, complexity theory tells us that a climate of cooperative social interaction, full of linguistic affordances (Van Lier, 2000, p. 252) which are perceived and used as appropriate, “produces new, elaborate, advanced psychological processes that are unavailable to the organism working in isolation” (Vygotsky, 1986, p. 61).

## **Unpredictability and Regularity**

Systems exhibit unpredictability, along with patterns of regularity. Taking the analogy of the weather as a complex system, modern day sophisticated equipment allows forecasters to predict (in the very short term) that it will rain in a given city on a given day. Meteorologists are finding, however, that whatever the level of sophistication of measurement, the outcomes of the complex interactions (connectivities) of the weather factors cannot be predicted with absolute certainty, so that it is not possible (even in the short



term) to predict that it will rain in any given locality (e.g., a school playing ground). In other words, the weather forecast is always at best an approximation, based on probabilities. However, as Stein writes, even these unpredictabilities show evidence of consistency:

Even though the behavior of the system is unpredictable in detail, surprising regularities nevertheless exist; for many diverse systems, the transition from regular to chaotic behavior shows certain universal features, independent of the details of the system ... a given experiment may have many outcomes, a given problem may have many solutions, all nearly equivalent, near optimal, with none much better than the rest. (Stein, 1989, pp. xiii-xv)

In terms of the EFL classroom, this principle can tell us that at the local level (equivalent to the school playing ground in the previous analogy), results cannot be predicted, and specifics of learning are unique to every individual. At the global level, however, regularities emerge from the sea of probabilities, and general outcomes can be determined. When teaching certain aspects of language, therefore, the teacher can offer the students various appropriate language-learning affordances and help them to work through these in groups, at their own speed, obtaining the learning input that is relevant to them, and moving on to other activities when they are satisfied. The final outcome will be similar, but the paths followed in arriving at that outcome will be different.

### **Equifinality**

The local unpredictability and global regularity of the preceding section point to another characteristic of complex systems: equifinality. While connectivities remain unique at the micro level, the outcome at the overall (global) level can be the same, or similar, in two different systems. This regularity of outcome can be applied in the language classroom, simply by observing that different students learn in different ways, though aiming at the

same goal. Even at the level of a single language lesson, with a stated learning goal, therefore, there are many ways of achieving that goal, all of them equally valid. This concept is particularly interesting in the context of project work. If we broaden our teaching/learning goals to development of critical thinking, problem-solving and learning strategies, for example, then student-directed language projects provide a means of achieving these goals in individually appropriate ways. Students working on an English class newspaper, a class webpage, or a group survey of local native speakers of English, for example, are all working towards the goal of target language linguistic fluency, but they are also following their own learning preferences/styles and employing their various multiple intelligences in ways that are appropriate to them. Rather than complaining that students have not all learned the same lexis, teachers can in fact be assured that students have all self-accessed the language which was appropriate to the learning situation, and have acquired this in meaningful, problem-solving contexts. As Dickinson and Carver note:

A language course can only deal with a small fraction of the foreign language; therefore one objective of language courses should be to teach learners how to carry on learning the language independently. (Dickenson & Carver, 1980, p. 1)

### **The Avalanche Effect**

Similar to the butterfly effect, this concept describes the outcome of a process of continuous emergence. When changing conditions are too drastic for local adjustments of the existing structure, natural systems evolve new structures and new functions, in phylogenesis. Thus, any pebble being thrown on a heap of pebbles on a mountain, cannot be expected to have a noticeable effect. However, as more and more pebbles are thrown onto the heap, there will be a time when they move in unison, and an avalanche occurs. The exact pebble which triggers this event cannot be predicted, just as the straw which “breaks the camel’s back” cannot be identified. The reality is that an

inflexible structure which refuses to adapt to changing conditions will eventually, at some unpredictable moment, cease to function. The event which causes such malfunction might seem insignificant, but will in actuality be simply one of innumerable connectivities. In this manner, pressures and processes in the language class can continue to build up until they reach a critical threshold; at which time they trigger sudden change. A groundswell of opinion about the inappropriateness of discrete-item, multiple choice, high-stakes testing, for example, might gradually compound itself until the inflexible testing system collapses, giving way to interdependence, complexity and differentiation, according to basic laws of evolutionary development. In order to prevent such potentially chaotic change, educational administrators will wish to replace a poorly advised crisis management approach with well-informed self-transformation, and it is significant at this time that the Ministry of Education and Human Resources in Korea has announced a “reform package aimed at changing the traditional school culture into a more autonomous and diverse one which will make students more creative” (BK 21, 2002).

## **SYSTEMS**

The individual learner has been seen for some time as a unique entity, with his/her own learning styles, learning preferences, multiple intelligences, perceptions, beliefs, and attitudes to learning, and the systems approach affirms such a perspective. However, systems theory also enables us to look at the learner in greater depth, and to explain why, for example, affect is more important than cognition in the learning process (Stern, 1993, p. 386). If we consider the traditional, teacher-led view of language learning, we find a provider of information, with the learner as passive recipient of that learning. The teacher “knows” what the learner “needs,” and is determined to provide it to the empty vessel in his/her charge. It is assumed that when the learner absorbs the knowledge provided, then the outcome will be successful,

quantifiable learning. Research into affect (cf. Arnold, 1999) has shown, however, that this is not the case (cf. Allwright, 1984), and that the inability of this model to produce results is not simply a matter of inadequate learners or teachers. Instead, Krashen's affective filters (Krashen, 1982) demonstrated that there are many factors impeding the supposed flow of learning from the teacher's jar to the learner's empty vessel, and that these non-causal, probabilistic factors had previously not been part of the learning algorithm. Low motivation, lack of confidence, poor self-esteem, anxiety, stress, passivity, beliefs about learning—these all became acknowledged as significant factors, and language learning suddenly became recognized as a complex event.

Teachers and researchers might well ask how the teacher is to promote language learning in this situation, when the student does not learn what the teacher teaches (Allwright, 1984), and when the path to learning is blocked by negative affect. How can valid and effective teaching take place, when every individual in the class is unique?

Modern SLA research has already suggested some directions from which to approach this situation. The focus on student-centred learning and autonomy has shifted the responsibility for learning to the learner, and has reclassified the teacher as a facilitator of learning. The macro- and micro-skills of counseling (Kelly, 1996), which are the teacher's new tools in this situation, require him/her to help students to become motivated to learn, to have self-esteem, to set realistic goals, and to assess their achievements effectively and accurately. Socio-linguistics has also offered an alternative view of learning, in which affordances (Van Lier, 2000) become the unit of learning. According to this view, the learning environment is likened to a forest, in which a leaf represents different things to different beings. To a caterpillar, for example, it might be a source of food; to a bird it might be nest-building material; to a frog it might afford shelter; and to a human it might be a source of medicine. The leaf remains unchanged, but the users of the leaf have different needs and use it in different ways. Applying this to the language learning classroom, we can think of lesson content as the leaf. The

teacher can promote and facilitate learning by setting up multiple learning affordances (content), which can be utilized in different ways by different learners, according to their proficiency levels, learning styles, perceptions and attitudes.

The forest provides us with a further analogy regarding systems and language learning. If we consider a single tree in the forest, we can view it as a complete system in itself, consisting of various subsystems (branches, leaves, bark, roots). As these subsystems interact, growth (subsequent emergence) is unpredictable – no one can tell how individual cells (local level) will form and what shape they will take, just as the combination of new cells cannot be predicted. What can be said, however, is that the overall structure (the result of all the unpredictable connectivities) of each system will take a form that is typical of that species of tree (global level). An observer will be able to say “That is an oak tree,” or “That is an oak leaf,” even though the shape of the leaf/tree is unique. At a further level, the tree is a system within a system, and it interacts with many systems, in similar vein to the learner in the classroom. The roots of the tree interact with the soil, which is the result of decomposition of plant and animal matter (including leaves from the tree itself), in addition to its alluvial or volcanic content. Insects and animals relate to the tree in various ways, as do other trees and plants. Water appears from underground sources or from rain, and even the weather is a contributory factor to the tree’s existence. It can thus be seen that the tree (or the learner) exists in relationship to everything around it, being influenced by and influencing all the systems with which it has contact.

At this point, it might be asked how research is to take place, and how teaching is to be adapted, if the classroom is a mutually influential collection of interactions and if each member of the classroom is an independent system within it. How can system and complexity concepts be used to investigate and enhance the classroom as an environment conducive to learning, when the very nature of a complex dynamic system means that results are probabilistic? Fortunately, it is not necessary to learn how to deal with differential equations and complex mathematical algorithms in order to

employ systems theory as a research tool, since the systems concept can be seen as a “guiding idea” rather than a mathematical construct and is still valid even when it cannot be formulated mathematically. When considering this guiding idea with relation to the language classroom (an open, man-made system in a socio-cultural setting), a number of organizational invariances of natural systems can be taken into account:

1. The classroom is a collection of natural systems (T, Ss), just as the forest is a collection of trees and animals;
2. Each mini-system influences, and is influenced by the larger sum-of-systems (the classroom);
3. This overall system is a whole, which cannot be reduced to its component properties;
4. The classroom maintains itself, though its participants may change;
5. The language-learning class is self-organising and self-creating in response to other systems (e.g., University entrance exams, parental pressure);
6. classroom exhibits equifinality; the same final goal may be realised in a number of different ways;
7. The classroom is a coordinating interface between other systems. The learners at one level interact with the teacher on the next level, who interacts with the school principal at a higher level. (Adapted from Laszlo, 2002, pp. 25-58)

These common characteristics lead in turn to a number of conclusions which can be drawn regarding a systems approach to teaching and learning:

1. A systems view of learning sees language acquisition and the learning environment from a holistic view, rather than as the sum of a number of components.
2. Equifinality can be applied in the language class by allowing students to work at their own speed, making learning achievements appropriate to their current status, from the learning affordances offered by the teacher.
3. Language learning can be approached from a humanistic perspective and can be seen as a linguistic, affective and social event which emerges with regularity from unpredictable interactions, but is greater than the

sum of those events.

4. The ELT/EFL class can be seen as an open system, with multiple subsystems (the participants). In this system, seemingly insignificant events can build up to critical thresholds, sparking sudden, irreversible shifts and new structures (the avalanche effect).

Thus, collaboration encourages positive connectivities, and student-centred project work promotes equifinality, while allowing the participants to respect their individual learning differences. This is not to advocate a complete process syllabus approach at every level of language learning, however. Such concepts can be incorporated into the beginner-level classroom, using a strong task-based approach. To take an example, the teacher of such a class might wish to introduce students to lexis and situations involving greetings and exchange of personal information. Instead of imposing the model language on the students out of context, however, it is possible to set up appropriate learning affordances, and to allow the students to take what they need from these. By offering a structured series of language-learning tasks, the teacher can promote discovery of relevant language, meaningful use of language, and intrinsic motivation. Groups of students who already possess much of the model language can move quickly on to the more demanding tasks, while those who are new to the topic can spend an appropriate amount of time learning the basics. Even in a multilevel class, every learner is involved in learning what is appropriate for him or her; the higher level students are being stretched with advanced problem-solving tasks; the lower level students are spending valuable time with the basics; everyone is experiencing task-completion and thus contributing to mutual respect and self-esteem; information is being shared and problem-solving strategies developed. When the lower level students decide that they would like to try another activity, they can see the activity (and the language) being modeled in the classroom by other groups, and can ask them for assistance.

It might be objected that students are learning different things in this situation, and that some are going slower (or faster) than others. However, this approach simply acknowledges that students learn at different rates and

in different ways. The problem in the linear, language-as-arithmetic mode, is that students who do not comprehend today's lesson content quickly fall behind and become unmotivated, as lesson content becomes more difficult. In a systems/complexity-based lesson, students can learn at their own rate, and can pay attention to the aspects of the language which they need to acquire. In this situation, everyone is learning something, and learned helplessness is not a problem. By providing structured tasks on the same basic topic, the teacher is enabling students to learn as much as they can, rather than requiring them to learn (at best) only that which is taught.

It might further be objected that assessment is a problem in such a learning environment. However, the conceptual shift from *what was learned* to *how it was learned* means that it is no longer important to find out whether every student has memorized the same lexis. Instead, educators need to know to what extent students have improved their linguistic, affective and social skills, and what areas could best be worked on by them. In this situation, self-assessment and peer-assessment are valuable educational tools, since they provide students with valuable self-appraisal skills, in addition to giving them important feedback (in a non-threatening context) on their learning.

Thus, a complex view of the classroom allows us to include emotions, intuitions and attitudes as valid factors in the learning environment. Every learner is different, and everything that has an influence on the learner is an interaction (or a connectivity) that can have unpredictable effects. The learning environment can be seen as a collection of learning opportunities which will be used in different ways by different students, so that students should be offered a non-threatening learning environment and allowed to follow their own learning path, finding new emergent structures as they progress, discovering for themselves the things that they need to know, and the skills they need to acquire.

## CONCLUSION

One of the major principles of complexity theory is that it is "a science of



process rather than state, of becoming rather than being” (Gleick, 1987, p. 5). Complexity theory allows us to view SLA as a dynamic, complex non-linear process that is open, self-organising, adaptive, unpredictable, and sensitive to initial conditions and feedback:

We can neither claim that learning is caused by environmental stimuli (the behaviorist position) nor that it is genetically determined (the innatist position). Rather, learning is the result of complex (and contingent) interactions between individual and environment. (Van Lier, 1996, p. 170)

Thus, Larsen-Freeman (1997) points to “many striking similarities between the new science of chaos/complexity and second language acquisition” (p. 141), and goes on to draw a number of chaos/complexity parallels in the language class: “languages go through periods of chaos and order as do other living systems. Furthermore, their creative growth occurs at the border between these two” (p. 158). This borderline between “order” and “chaos”, or the point at which the system is about to become chaotic (e.g., just before an avalanche) has been termed “the edge of chaos” by Waldrop (1992, p. 198), who also coined the term “life at the edge of chaos” to describe the capacity for learning that complex adaptive systems have when they are neither settled nor chaotic - a concept with various implications for the language classroom and for the autonomous learner:

The educational context, with the classroom at its center, is viewed as a complex system in which events do not occur in linear causal fashion, but in which a multitude of forces interact in complex, self-organizing ways, and create changes and patterns that are part predictable, part unpredictable. (Van Lier, 1996, p. 148)

Systems-thinking tells us that relationships are more important than isolated entities and complexity theory amplifies this, pointing to connectivity as the essential characteristic of complex systems (such as the language classroom), in which constituent parts interact to produce self-organisation, from which unpredictable higher-order structures emerge. Applying this to

the language classroom, interactions between participants are important events, from which exponentially expanding results can emerge. Minor differences in initial conditions can result in completely different outcomes. Thus, seemingly insignificant occurrences in the classroom are part of the whole process of growth, setting off further interactions and learning experiences (Gleick, 1987, p. 8). Allowing for such divergent learning events and being ready to accommodate and discuss them is implicit in the “complex” approach to the language classroom, and to the dynamics of process:

The dynamics of process revolve around issues such as authority and self-determination; co-operation and competition; expectation and motivation; the individual and the group; security and risk; failure and success; self-esteem and its absence; personal meaning; and how participants feel, think, and act in relation to themselves, to each other, and to what they are doing. Teachers who claim it is not their job to take these phenomena into account may miss out on some of the most essential ingredients in the management of successful learning. (Underhill, 1989, p. 251)

Research into such a view of language learning should take the form of triangulated observation over the long term. In addition to chronicling the learning events and interactions in the classroom, it would also be necessary to observe how these impact (and are impacted upon by) other systems such as family and friends. As Byrne notes, this world is “so complex that it can only be known through measurement of indicators of the character of the social system as a whole” (Byrne, 1998, p. 9). This would seem to be an impossible task, with interactions (non-additive effects of multiple variables) becoming non-quantifiable, just as the game of Go cannot be mastered by a computer. When we examine the strategies of Dan-level Go players, however, we find a different approach to the game, one based on *how a move looks* (pattern recognition) and *how a move feels* (positive affect). It is this sort of global approach that must be attempted, in a search for emerging regularities. Results will not be in terms of quantifiable language proficiency, but as Van

Lier points out:

It is quite possible that the deepest, most satisfying aspects of achievement, and the most profound effects of education, both in positive and negative terms, are entirely unmeasurable. (Lier, 1996, p. 120)

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