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Plenary Speeches

Complex, dynamic systems: A new transdisciplinary theme for applied linguistics?

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In this plenary address, I suggest that Complexity Theory has the potential to contribute a transdisciplinary theme to applied linguistics. Transdisciplinary themes supersede disciplines and spur new kinds of creative activity (Halliday 2001 [1990]). Investigating complex systems requires researchers to pay attention to system dynamics. Since applied linguists study language systems that change (for example, as they develop in learners), this is a useful perspective to bring to bear on many of our concerns. To introduce Complexity Theory, I list twelve principles undergirding this perspective and elaborate on three of them: those to do with dynamism, complexity, and the role of context. I then discuss several studies of L2 development that have been informed by the perspective. I conclude by suggesting that the ultimate promise of Complexity Theory is the help it provides in humanizing science.

1. Introduction

The moving figure you see on the screen is a fractal. Mesmerizing, isn't it? This particular figure is named for the mathematician Benoît Mandlebrot, who coined the term 'fractal' to refer to structures that are self-similar on every level of scale. As it is projected here, it is iterating, taking us deeper and deeper into the structure where we see the same pattern repeated. Fractals occur commonly in nature, the product of dynamic systems. I would like you to hold this image in mind today, as I speak about a theory with which fractals are associated, namely Complexity Theory.

For some time, I have been intrigued by the perspective Complexity Theory affords us to think anew about our objects of concern as applied linguists (Larsen-Freeman 1997). Although originating in the physical sciences and mathematics, Complexity Theory (CT) inspires us to think differently about language and language development – especially with regard to their complexity and dynamism, qualities which have received short shrift, at least from mainstream linguists and applied linguists. Its way of thinking challenges the dominant 'preformationist' paradigms of the field, and the very notion that knowledge structures or schemas of competence guide performances and account for their invariant features.

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Although some of you might be put off by its origin in the natural sciences, you may be reassured by the fact that CT has been embraced by a range of disciplines from biology to organizational development to epidemiology. Indeed, the French philosopher and sociologist, Edgar Morin, finds in complex thought an approach to many of the vexing issues that we humans struggle with at this time. And South African philosopher, Paul Cilliers, finds in it philosophical grounds on which to challenge injustice in the world.

What I want to focus on today, though, is the case for complexity as a transdisciplinary theme. I will begin by discussing what a discipline is. I will then move to considering its derivatives: multidisciplinary, crossdisciplinary, interdisciplinary, and finally, transdisciplinary. Following a discussion of this taxonomy, I will list some principles of Complexity Theory, elaborating upon three of them. I will then briefly point to their value in thinking about and researching second language (L2) development.

2. Disciplinary knowledge and its variations

In the words of the social scientist Raymond Miller (1982: 6)[1], a discipline is a 'conceptual framework'. Members of a discipline, by virtue of their training and initiation into that discipline, have acquired 'a sense of order, of what is real and how knowledge is obtained'. Halliday (1991: 42) has observed that the twentieth century has been the age of disciplines, with each having its own theories and methods. In keeping with this observation, Morin (2007) cites 'the principle of disjunction', whereby disciplines have become hermetic from one another. These days, however, disciplinary boundaries are being torn down (Halliday 1991). Although disciplines have made valuable contributions to our understanding, at the same time, they constrain what is legitimate to look at and which theories can be brought to bear to interpret findings. Applied linguists, by virtue of not having a disciplinary home, have happily not been subject to the same constraints. I say 'happily' because disciplinary knowledge is always partial and provisional, and unless one gets outside of a discipline, such limitations are not always apparent (Widdowson 2005).

Given the present state of affairs, with new hybrids being created all the time ('neuroeconomics' is one that I have heard recently), it is perhaps time to heed Morin's call for replacing the principle of disjunction with a principle that maintains the distinctive nature of the disciplines, but that seeks to establish a relationship among them. One way to accomplish this might be to adopt a multidisciplinary approach. The problem with multidisciplinary approaches is, however, that they are additive (Moran 1994: 49), with each discipline contributing its perspective on an issue, but with no interaction among the disciplines. This results in little or no subsequent modification of views among the contributing disciplines.

More promising then, perhaps, are crossdisciplinary approaches that involve an effort at moving across disciplinary boundaries. For example, last year, Elinor Ostrom of Indiana University became the first woman to win the Nobel Prize for economics. Also noteworthy is that her background is in political science, not economics. '"It is part of the merging of the

[1] As cited in Moran (1994).

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social sciences", Robert J. Shiller, an economist at Yale, said of the award. "Economics has been too isolated. . ." (*New York Times,* New York edition, 13 October 2009, page B1).

However, the drawback to a crossdisciplinary approach is that 'it is not simply a matter of coupling two disciplines together, with each retaining its own identity and integrity, but of one discipline assuming a dominant role and drawing upon the other whatever can be accommodated within its scheme of things. . . As a consequence, of course, the adaptation will always be open to the charge of distortion' (Widdowson 2005: 18). For example, Widdowson notes that Joshua Fishman has discussed the field of sociolinguistics, and has argued that it has failed to deal adequately with ideas from sociology.[2]

Interdisciplinary approaches are another variation to be considered. These days our universities are fond of promoting interdisciplinarity. However, an issue with interdisciplinarity is that 'it is simply not possible to see things from two different perspectives at the same time. You can, of course, shift from one perspective to another at different times, and this can often prove enlightening, if only to show how incomplete and partial different representations of reality can be' (Widdowson 2005: 19).

The interdisciplinarity of applied linguistics is widely acknowledged, but, aside from linguistics, there has been little discussion of the nature of the relationship among the disciplines that inform it, other than to acknowledge their contribution to theoretical aspects. So we are left with our dilemma. A solution might be to break with discipline-bound concepts. Such is the case with transdisciplinarity or with a transdisciplinary approach, as suggested by Miller (1982: 21).

> Transdisciplinary approaches are articulated conceptual frameworks which claim to transcend the narrow scope of disciplinary world views and metaphorically encompass the several parts of the material field which are handled separately by the individual specialized disciplines.

In his interview (2006) with Anne Burns in the *Journal of Applied Linguistics*, Halliday also speaks of transdisciplinarity and adds that it not only avoids the fragmentation of disciplinary knowledge, it also redefines the structure of knowledge. In an earlier publication, Halliday put it this way:

> I say 'transdisciplinary' rather than 'inter-' or 'multi-disciplinary' because the latter terms seem to me to imply that one still retains the disciplines as the locus of intellectual activity, while building bridges between them, or assembling them into a collection; whereas the real alternative is to supersede them, creating new forms of activity which are thematic rather than disciplinary in their orientation. (2001 [1990]: 176)

Halliday (1991) elaborates by noting that in the nineteenth century, evolution became a theme of this kind: it embodied the concept of history, the 'arrow of time' which had been missing from the physical sciences and which they were then ready to bring back. An evolutionary perspective was widely adopted by the physical sciences. 'But the human sciences were not ready for it. They still lacked the sense of a system, a model of how any form of organization persists; so in the following period they developed their own theme, that of structuralism.

[2] I must acknowledge that I take the same risk in appropriating a theory from the physical sciences, as I have done with Complexity Theory.

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Change had to be taken off the agenda so that we could study how human systems were organized' (Halliday 1991: 42).

3. Complexity Theory/Dynamic Systems Theory[3]

I believe we have reached a point where change can be put back on the agenda. And that is what I think Complexity Theory/Dynamic Systems Theory (CT/DST) encourages us to do. Before going on, however, I should note that the word 'theory' in CT/DST is not singular, but rather, represents a range of theoretical insights that call into question some of the assumptions that have been used to inform and to structure research for many years. As developmental psychologists Smith & Thelen (1993: xii) write:

> [Dynamic Systems Theory] is being used by researchers and theorists for many different levels of analysis, for behavior ranging from the physiologic to the social, and for describing change over time scales from seconds to years. We see this diversity, however, not as a failing of the approach, but indeed as its real strength… [Nevertheless, w]e are alert to the pitfalls of explaining too much by a single, overarching organization. It seems to us that the future of [Dynamic Systems Theory] will lie with very general principles of process and change, applicable in many domains, over many levels and time scales, but also allowing the multiple local details to emerge from the necessary empirical work.

So what are the general principles of process and change that Smith & Thelen allude to? Here are twelve that I have compiled (see also Cilliers 2008 and de Bot & Larsen-Freeman, forthcoming). I realize that if you know nothing about CT/DST, these may be difficult to understand. I will try to make three of them, at least, more comprehensible by elaborating on them in a moment (for the discussion of other principles, see Larsen-Freeman 1997; Larsen-Freeman & Cameron 2008).

1. Complex systems are open and dynamic.
2. They operate under conditions that are not in equilibrium.
3. Complex systems are systems because they comprise many elements or agents, which interact.
4. Change/dynamism is central. The systems adapt both through interaction with the environment and through internal reorganization/self-organization.
5. The strength of the interactions changes over time. Therefore, multiple routes are often possible between components, mediated in different ways.
6. The complexity of complex systems is emergent. It is not built into any one element or agent, but rather arises from their interaction.
7. Because the systems are open, what arises may be in nonlinear relation to its cause. In other words, an unexpected occurrence may take place at any time.
8. The structure of a complex system is maintained even though its components may change.
9. The environment in which they operate is part of a complex system.

[3] Although they have different origins, Dynamic Systems Theory (de Bot, Lowie & Verspoor 2005, 2007; de Bot 2008) has much in common with Complexity Theory, so for my purposes here I will not distinguish them.

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10. Complex systems display behavior over a range of timescales and at different levels of complexity – the latter are nested, one within another.
11. Complex systems sometimes display chaotic variation.
12. Complex systems iterate – they revisit the same territory again and again, which means that the present level of development is critically dependent on what preceded it.

Let me now elaborate a bit on three of these.

3.1. Principle #4: Change/dynamism is central to our objects of concern.

Dynamic change in the form of language evolution, language processing, language change, language use, language acquisition, language development, etc. is central to our concerns as applied linguists; nevertheless, the process by which things unfold dynamically has gotten rather short-shrift in applied linguistics. As Jeff Elman (2003: 430) has said of language development:

> Development: It's about time. Well, other things too. But what is surprising is that, with a few notable exceptions, very little work in developmental research seems to focus on what is most striking about development, namely, that it involves change over time. This tendency to study development as if it were a succession of snap-shots – frozen in time and fixed – is more than odd. It biases the theoretical perspective, favoring theories in which the origins of behavior are of minimal interest.

Halliday also anticipated the need to introduce or to reintroduce a dynamic perspective into applied linguistics. 'It is useful, he suggests, both to capture a phenomenon *qua* object at a particular moment in time (synoptic) as well as to tease out the processes through which a phenomenon unfolds (dynamic)' (Halliday 2007 [1990]: 362, cited in Hult 2010). Sounding a similar note, Ellis & Larsen-Freeman (2006) proposed that theories of language representation (property theories) and theories of language acquisition and use (transition theories) are complementary; yet the two have been kept distinct. In CT/DST a property theory and a transition theory can be integrated because development (which must be viewed dynamically) is seen to result in a certain stability (which can be viewed synoptically), which is then the starting point for further unfolding.

In short, Plato and Heraclitus were both right – but Plato has had his way with us recently. In our daily lives complexity and constant change can be difficult to live with. We cope by reducing the complexity – by adopting routines and telling stories about our life experiences, and by reifying constant change, for instance, nominalizing dynamic processes, which then connotes stasis (Larsen-Freeman & Cameron 2008). We give a language a name as if its borders were defined and it existed as a separate entity. The same preference for an artifice of simplicity and fixity appears in our scholarly work. Change is inherent in most of our concerns as applied linguists, and yet in our theories we everywhere find processes converted into objects. CT/DST restores the dynamism to our objects of concern. CT/DST aims to account for how the interacting parts of a complex system give rise to the system's collective behavior and how such a system simultaneously interacts with its environment. This brings me to a second principle.

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3.2. Principle #6: The complexity of complex systems is emergent. It is not built into any one element or agent, but rather arises from their interaction.

Alice Munro, the Canadian writer, once said 'The complexity of things – the things within things – just seems to be endless. I mean nothing is easy, nothing is simple' (Franzen 2004). Nothing of interest to applied linguistics, I would add. Recall the image of the fractal that I showed you at the beginning of my talk. Complex things within complex things might be a good way to describe a fractal.

However, in CT/DST, 'complex' does not merely mean 'complicated'. Although the components of a complex system are usually numerous, diverse, and dynamic, a defining characteristic of a complex system is that its behavior emerges from the interactions of its components, as in flocking birds or schooling fish.

> . . .and the thousands of fishes moved as a huge beast, piercing the water. They appear united, inexorably bound by common fate. How comes this unity? (Anonymous)

CT/DST's answer to this question about unity is that the school of fish emerges out of the interaction of the individual fish. There is no lead fish exhorting the others to form a school. There is no pre-set pattern (preformativism). Instead, a school of fish emerges and then adapts itself to a changing environment – forming and reforming in response. This process of forming through interaction of the parts of a system is called self-organization. In other words, self-organization is the spontaneous creation of more complex order. It refers to 'any set of processes in which order emerges from the interaction of the components of system without direction from external factors and without a plan of the order embedded in any individual component' (Mitchell 2003: 6). Self-organization is responsible for the patterns and orderly arrangement both in the natural world and in the realms of mind, society and culture (Heylighen 2008). However, it is not just that things are ordered.

> Order is not sufficient. What is required is something much more complex. It is order entering upon novelty; so that the massiveness of order does not degenerate into mere repetition; and so that the novelty is always reflected upon a background of system (Whitehead 1978: 339).

Thus, complexity is creative – it helps a system to go beyond, to grow. We see an example of this in our everyday society.

> [As] we interact with ever more people, organisations, systems and objects [a]nd as the network of interactions grows and spreads around the globe, the different economic, social, technological and ecological systems that we are part of become ever more interdependent. The result is an ever more complex 'system of systems' where a change in any component may affect virtually any other component, and that in a mostly unpredictable manner (Heylighen, Cilliers & Gershenson 2007: 117).

The traditional scientific method, which is based on analysis, isolation, and the gathering of COMPLETE information about a phenomenon, is incapable of dealing with such complex interdependencies. One of the reasons that we can never have complete information about a system is that 'a system is never optimally adapted to an environment since the process of

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evolution of the system will itself change the environment so that a new adaptation is needed, and so on. . .' (Heylighen 1989). Heylighen's observation brings up the third principle I will comment upon, one having to do with the importance of the context.

3.3. Principle #9: The environment in which complex systems operate is part of a complex system. Context is all important.

It is not uncommon for researchers to discuss the context as if it were a backdrop to what is of focal interest. However, CT/DST challenges the idea that context is background to the main action. It sees the context as part of the complex system. The philosopher Paul Cilliers put it this way: because everything is always interacting and interfacing with others and the environment organically, the notions of 'inside' a system and 'outside' a system are never simple or uncontested (Cilliers 2001: 142). The geneticist and Nobel laureate in physiology, Barbara McClintock, gives us a glimpse of what this means in practice (Briggs & Peat 1989: 201–202):

> Basically, everything is one. There is no way in which you draw a line between things. What we [normally] do is to make these subdivisions, but they're not real.

Though McClintock arrived at this sense of oneness by focusing on parts (in particular on the chromosome) with an almost reductionist fervor, her approach is not reductionist or 'objective' in the traditional sense.

> I found that the more I worked with them the bigger and bigger [the chromosomes] got, and when I was really working with them I wasn't outside, I was down there. I was part of the system.

Cancer researcher Mina Bissell (*New York Times*, 29 December 2009) provides us with another example of the importance of challenging the inside/outside dichotomy. For years, researchers have been pursuing the hypothesis that cancer is caused by rogue cells that come from genetic mutations. Bissell proposed a radical idea: Gene mutations are part of the process of cancer, but they alone are insufficient to explain how cancer occurs. Cancer involves an interaction between rogue cells AND surrounding tissue. This new focus on a cancer's surroundings or context represents a paradigm shift in how to think about cancer and why it occurs. . .and perhaps how to stop it.

> Life is defined by where we draw the lines. The fact that defining these boundaries is so difficult is part of what makes life interesting. All boundaries are no more than temporary patterns resulting from a filtering process. . . As such, they are to some degree arbitrary. . .and require ongoing review to understand how they shape our context of interest – and how our context of interest shapes them (*General Systems Bulletin* XXXIX: 38 – Call for the First International Workshop on Complexity and Real World Applications, 21–23 July 2010, International Society for the Systems Sciences, 2010).

Of course, it is humanly impossible to study everything at once. 'Boundaries are still required if we want to talk about complex systems in a meaningful way – they are in fact necessary. . .' (Cilliers 2005: 612); however, there are strategic considerations at stake when drawing them.

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Therefore, we need at least to recognize the challenge in defining a focal point for our investigations. As Atkinson et al. (2007) write, we need to view mind, body, and world relationally and integratively – as constituting a single ecological circuit.

Identifying the functional whole, then, is key. And this leads to the challenge to find new functional ways of conceptualizing and perceiving, changing our 'objects of concern' into processes, change, and continuities. . .and doing so in a way that does not decontextualize them. Thelen & Smith (1994: 217) put it this way: '. . .since the global order is made by and made manifest in the details of the here and now, it is most fundamentally always context dependent'. Byrne concludes: 'Complexity theory challenges the nomothetic programme of universally applicable knowledge at its very heart – it asserts that knowledge must be contextual' (Byrne 2005: 97).

Not much of what I have said thus far has dealt with language or its development. I now briefly take these up in a way that has been illuminated by CT/DST. Linguist Dwight Bolinger (1996: 5), although not explicitly invoking CT/DST, rendered a definition of language that is certainly in keeping with Complexity Theory:

> English is a godawful mixture of irregularities growing out of competing regularities – a perpetual cliffhanger where one crisis resolves itself by creating another and the permanent solution always waits for tomorrow.

The fact of the matter is that the stability of language only becomes possible through constant change. Language is a complex, adaptive system.[4] Larsen-Freeman & Cameron (2008: 111–112) articulated the concept this way:

> Viewing language as a complex system makes us regard linguistic signs not as 'autonomous objects of any kind, either social or psychological', but as 'contextualised products of the integration of various activities by [particular] individuals in particular communicative situations' (Harris 1993: 311), what we have called their language resources. 'It logically follows that they are continually created to meet new needs and circumstances. . .' (Toolan 2003: 125). Complexity theory encourages us to link real-time processing and all its variability to change over time. The value of this perspective is that language is no longer perceived as an idealised, objectified, atemporal, mechanistic 'thing' (Rutherford 1987).

The earlier quote from Smith & Thelen (1993) makes it clear that general CT/DST principles have to be accompanied by the necessary local empirical work. So what are some examples of the necessary empirical work being done in the name of CT/DST? In particular, how has CT/DST informed L2 development?[5]

4. Empirical work in L2 development

For much of the second half of the last century, the dominant metaphor for L2 development was the digital computer. One manifestation of this is the ubiquity of terms like 'input'

[4] See the Special Issue of *Language Learning*, December 2009, edited by Ellis & Larsen-Freeman, featuring this theme.
[5] In the plenary address I discussed many more areas of applied linguistics that had been influenced by CT/DST, even if not directly and not necessarily by a single intact theory. Here I will limit the discussion to L2 development.

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and 'output'. Accompanying those terms was a characterization of the process of language use as a rule-based manipulation of symbols. Consequently, researchers put their efforts into searching for universal stage-like progression in the acquisition of rules towards full competence. Influenced by CT/DST, some researchers have shifted their efforts to not only looking for stabilities, but also to examining the flexible, transient, dynamic patterns of learner language which emerge from use (Ellis & Larsen-Freeman 2006). 'Language development is no longer seen as a process of acquiring abstract rules, but as the EMERGENCE of language abilities in REAL TIME, where changes over days, months, and years and moment-to-moment changes in language 'processing' are the same phenomena, differing only in their timescales' (Evans 2007: 131). To this end, Kramsch & Whiteside (2008) report on empirical work in L2 use in an immigrant community that supports this last point: Language phenomena emerge at a particular level or scale as a result of activity at a lower level or from an earlier period.

Ellis with Larsen-Freeman (2009), following work by L1 acquisition researchers Tomasello (2003) and Goldberg (2006), have reported on the acquisition of English verb-argument constructions (VACs) by EFL learners from a usage-based perspective. They suggest that learners appear to induce categories from exemplars centered on verbs prototypical of a particular VAC, prototypical verbs being overwhelmingly prevalent in the language spoken to learners. Perhaps not surprisingly, when the learners begin to produce VACs, the first verb to emerge for a VAC is the one with the highest frequency. Thus, the use by speakers of such highly frequent exemplars when addressing learners presumably facilitates comprehension in the micro-discursive moment, and perhaps facilitates their subsequent emergence in learner production.

Ellis with Larsen-Freeman went on to use computer simulations to see if they would pattern VAC data in a similar manner to the learners. Although decontexualized, computer simulations allow for the investigation of dynamic interactions of these factors in language learning, processing, and use. In fact, the simulations showed how simple iterated general learning mechanisms, exposed to the co-adapted language usage typical of speech to learners, produced the same order of emergence as that which characterized learner production, and used the same cues. Learning takes place through continually revisiting the same space over and over again.

The suggestion that a developing system functions as a resource for its own further development calls into question whether it is possible to separate the learner from learning. Indeed, as Kramsch (2002) observes, it 'is no longer sufficient to talk about individual differences in SLA [second language acquisition] against a backdrop of a universal learner. . .variation becomes the primary given; categorization becomes an artificial construct of institutionalization and scientific inquiry' (Kramsch 2002: 4); paraphrasing Yeats, she adds: 'it may not be possible 'to tell the dancer from the dance'. Kramsch's notion of symbolic competence also fits well within a CT/DST perspective because it is an 'ability not only to approximate or appropriate for oneself someone else's language, but to shape the very context in which one learns and uses the language' (Kramsch 2008: 400).

Dörnyei (2009) has recently suggested that the seemingly comprehensive and straightforward picture of individual differences as stable and monolithic learner traits that concern distinct learner characteristics is part of an idealized narrative. He notes that if we take a situated and process-oriented perspective on SLA, we cannot fail to realize that the

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various learner attributes display a considerable amount of variation from time to time and from situation to situation. As he notes, seeking an explanation for individual differences in cause-effect patterns and generalizable findings does not fit a Complexity Theory perspective.

I suggested in my own study of five Chinese learners of English (Larsen-Freeman 2006; see also de Bot, Lowie & Verspoor 2005, 2007) that the difference between the performance of learners is not 'noise', but rather a natural part of dynamically emergent behavior assembled by individuals with different orientations, grounded in social relationships with other people, and in keeping with historical contingency. From a CT/DST perspective, flux is an integral part of any system. It is not as though there was some norm from which individuals deviate. Variability stems from the ongoing self-organization of systems of activity.

Macqueen (2009) also adopted a CT/DST perspective in her investigation of the development of four ESL learners' writing. A qualitative methodology (Lexical Trail Analysis) was used to capture a dynamic and historical view of the lexicogrammatical patterning in the learners' writing. Recurring patterns were traced, and the adaptations that learners made were noted. Macqueen's results demonstrate learners' ability to imitate and to adapt, and thus transform their language resources. 'Adaptive imitation is the means of gaining the power to conform and the power to create. This power is what enables reciprocal causality in language patterning where. . .the communication patterns of individual people contribute to the prevailing norms of their discourse communities. . .' (p. 266).

Larsen-Freeman & Cameron (2008: 158) have written in this way about the process of L2 development. 'Embodied learners soft assemble their language resources interacting with a changing environment. As they do so, their language resources change. Learning is not the taking in of linguistic forms by learners, but the constant adaptation and enactment of language-using patterns in the service of meaning-making in response to the affordances that emerge in a dynamic communicative situation'. Thus, this view assumes that language development is not about learning and manipulating abstract symbols, but is enacted in real-life experiences, such as when two or more interlocutors co-adapt during an interaction. During co-adaptation, the language resources of both are transformed through reciprocal causality.

There have been others, too, who have used a CT/DST perspective to advance their research agendas. For instance, Meara (2006) used dynamic modeling to describe vocabulary development or loss, and Herdina & Jessner (2002) used it to discuss changes in multilingual proficiency on an individual level and to provide a more dynamic description of multilingualism. More empirical work has been done, and is being done, all the time. These few examples will have to suffice to support my belief that CT/DST offers a valuable transdisciplinary theme, having general principles that promote the necessary local empirical work and 'creating new forms of activity which are thematic rather than disciplinary in their orientation' (Halliday 2001 [1990]: 176).

5. Conclusion

As I conclude, I would like to draw your attention once more to the image on the screen. In a moment, I will play for you a brief episode from the program *Nature* that appeared recently on

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the Public Broadcasting System. It depicts a flock of starlings looking to roost for the night. As they circle, they form a flock. The flock flows from one amorphous figure to another forming and reforming over and over, before alighting in a grove of trees. The commentator observes that they seem to function as a super-organism – at a level of complexity beyond that of individual birds. This super-organism is a fitting symbol of Complexity Theory, an emergent figure that has self-organized from the interaction of its individual components.

Morin (2007) makes the point that we humans have been better prepared by our education to separate than to connect. Because of this, our ability to connect has languished. A transdisciplinary theme helps us to reverse this trend. As Morin (2008: vii) states:

> We need a new kind of thinking that reconnects that which is disjointed and compartmentalized, that respects diversity as it recognizes unity, and that tries to discern interdependencies.

Not only is it a problem in our modern world that we fail to recognize and respect our interdependence, it is also a problem that we do not appreciate the complexity of the world we live in. As Nowotny, Scott & Gibbons (2001: 21) put it 'Contemporary society is characterized – irreversibly – by pluralism and diversity and also, we argue, volatility and transgressivity. It can no longer be understood either in terms of the norms or practices of scientific rationality. . .'.

The price we pay for clinging to a modernist rationality can be seen on many levels in our interdependent, complex, globalized world. Perhaps the most important one is the distortion it brings to our understanding of what it is to be human. As Horn (2008: 140) writes, 'In attempting to make the human sciences objective, the human became turned into an object'. Thus, the ultimate promise of CT/DST is to 'help us to humanize science, not the other way round' (Cilliers 2008: 50).

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