Studies in Second Language Learning and Teaching
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SSLLT 6 (3). 2016. 377-393
doi: 10.14746/ssllt.2016.6.3.2
http://www.ssllt.amu.edu.pl

Classroom-oriented research from a complex systems perspective[1]

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Abstract

Bringing a complex systems perspective to bear on classroom-oriented research challenges researchers to think differently, seeing the classroom ecology as one dynamic system nested in a hierarchy of such systems at different levels of scale, all of which are spatially and temporally situated. This article begins with an introduction to complex dynamic systems theory, in which challenges to traditional ways of conducting classroom research are interwoven. It concludes with suggestions for research methods that are more consistent with the theory. Research does not become easier when approached from a complex systems perspective, but it has the virtue of reflecting the way the world works.

Keywords: complex systems; emergence; intra-variability; inter-variability; research methods

[1] This article is based on a revised and updated paper delivered at the Classroom-Oriented Research: Towards Effective Learning and Teaching Conference, Konin, Poland, October 12-14, 2015. I am grateful to Mark Clarke and two anonymous reviewers for their comments on an earlier draft of this article and to Mirek Pawlak for his invitation to present a paper at the conference.

1. Introduction

Classroom-oriented research is important—especially when it is explicitly directed towards understanding effective learning and teaching—which is the theme of the conference in which the paper that this article was based on was presented. However, it is my contention that classroom-oriented research has not contributed towards this effectiveness to the extent that it might because our construction of the classroom has been too limited. I submit that complex dynamic systems theory (CDST) has the potential to broaden our perspective appropriately. I therefore begin by discussing characteristics of complex systems and the implications of these characteristics for research. As part of this discussion, I maintain that conducting educational research from the viewpoint of complex systems calls for a departure from standard epistemological assumptions. For instance, CDST questions the value of randomized control experiments for classroom-oriented research, even though such experiments have often been considered "the gold standard." It also challenges the idea that the results of a given study can be replicated. I will conclude the article with a discussion of certain methods for conducting classroom-oriented research that do make more sense from a CDST perspective. In so doing, I am not assuming that findings from classroom-oriented research should be directly applicable to teaching, a point I shall return to at the end of this article.

2. Characteristics of complex systems

Probably the most distinctive, and certainly the most intriguing characteristic of complex systems is their emergence. Emergence is the arising of something new, often unanticipated, from the interaction of components which comprise it. Emergent behavior can be observed in everything from bird flocks to traffic gridlocks. In the case of the classroom ecology, the components are not only the agents, that is, the teacher and the students (and all of their accompanying thoughts, embodied actions, emotions, behaviors, dispositions, identities, social capital, etc.), but they also include properties of the physical and temporal environment as well. For instance, the configuration of the desks, the size of the room, its orientation, its temperature, the time of the day/week/year at which the lesson is conducted, and so on, all potentially influence teaching and learning. In a complex system, the physical environment is not considered a backdrop but is rather integral to what emerges from agents interacting with it. It is not difficult to imagine, for instance, how the pattern dynamics would be altered in a classroom with desks affixed to the floor so that interaction among students is impeded, or in my case, in teaching English in Malaysia, how heavy rains on

the corrugated tin roofs of our open air classrooms kept our voices from being audible, and thus, during the rainy season, frequently disrupted spoken interaction of any kind. In other words, we cannot make assertions about effective teaching and learning without considering the environment in which it is embedded.

But more than the physical presence of these factors in the environment, what is key is how the agents relate to them. CDST is a relational theory. This is why I wrote that the environmental factors were "potentially" influential. What is important for teaching and learning is not simply the presence of environmental influences; it is how the agents perceive them as offering the basis for action (Larsen-Freeman, 2016; Mercer, 2016; van Lier, 2004). Both teacher and learner agency "emerges from the interaction between resources and contexts and the learners' [and teachers'] perceptions and use of them" (Mercer, 2012, p. 43).

At the same time, it is important to recognize that the class itself is one of many systems nested within other systems. My class in Malaysia existed within a government secondary school, which was part of a school district with other schools. The district, in turn, was a subsystem of the State of Sabah's Ministry of Education in Kota Kinabalu, and then it, too, was under the umbrella of the national Ministry of Education, situated in Kuala Lumpur. The systems are not only nested one within another; each also influences what transpires above and below any given level.

Thus, a complex dynamic systems perspective asks us to consider interaction across interconnected levels of organization, with each level itself a system of interacting components and with the levels forming a hierarchy—in the case of classroom-oriented research, a hierarchy from individual minds up to the sociopolitical context of language learning and teaching. As Goldstone (2006) notes, the way a component behaves is shaped by the larger system of which it is a part. Furthermore, at all levels, dynamic behavior is taking place at the same time.

Speaking of time, it is significant that a complex system is temporally situated as well. Emergence is not only affected by what is taking place at one point in time, but it is also the product of dynamism over time. A complex system is made up of interconnected timescales, from the moment-by-moment scale of classroom activity to teaching and learning lifetimes (Cameron & Larsen-Freeman, 2007, p. 236). Because of the dynamic quality of classrooms as complex systems, circumstances change. For instance, as students show that they are learning, teachers alter the tasks they assign, perhaps increasing their authenticity; they lessen scaffolding; they adjust any expectations they have, the opportunities they provide, and so forth (van Geert, 2011). If all this seems complicated (although I caution that complicated and complexity are not equivalent terms within CDST), well, it is. "With the . . . emergence of complexity as an overarching explanation of reality, our fundamental assumptions about the way the world works, including comfortable understandings about teaching and learning, require serious scrutiny" (Clarke & QuinnWilliams, 2015, p. 4).

Contrast this appraisal of emergent complexity in the classroom with Bolster's (1983) depiction of traditional classroom research:

> . . . much social science research on teaching assumes that causation in classrooms operates unilaterally from the teacher to the students . . . teaching is viewed exclusively in terms of the influence instructors have on pupils; the reciprocal effects of students on teachers or of students on students and then on teachers are thought to be either nonexistent or not of central consequence. (p. 302)

While Bolster's assessment is somewhat dated, I believe that a unilateral linear view of teaching and learning still prevails. In contrast, in complex systems, it is understood that it is highly unlikely that a single cause will give rise (in a linear fashion) to a complex event. Rather, there are likely multiple and interconnected causes underlying any shift or outcome. "We may rank their relative significance, but we'd think it irresponsible to seek to isolate – or 'tease out' – single causes for complex events" (Gaddis, 2002, p. 65). This is an important point because the world as envisioned by CDST does not rest on assumptions of linear causality. "Simple point-to-point causal explanations are of limited value; that is, you can't prescribe simple solutions for the problems that matter" (Clark & QuinnWilliams, 2015, p. 2).

As I mentioned earlier, complex systems are situated not only in space, but also in time. For instance, the current state of a complex system is shaped by all of the events of its history and by the events of the moment, and by our perspective on all of this. Complex systems are, in Gould's (as cited in Rosenberg, 1990) words, "the result of a series of highly contingent events that would not happen again if we could rewind the tape" (p. 1). One consequence of the temporal embeddedness of a complex system is that ". . . conclusions about the eventual attainment are strongly dependent on the coincidental time of the measurement" (Lowie & Verspoor, 2015, p. 66).

Therefore, "[one type of] research on teaching requires direct systematic continuous observation (preferably recording) supplemented with interviews in order to capture, as far as possible, the ways individual students experience their classroom activities and the curriculum content embedded in them" (Nuthall, 2004, p. 296). Nuthall goes on to observe that

> teaching effects are not stable over time and context, and both teaching and learning are continuous, cumulative processes. Recordings and observations need to be focused on individual students. Occasional observations or sampled observations do not provide the data needed to connect teaching to the learning process.

Of course, second language classroom-oriented researchers do have access to other means of studying classroom interaction. For example, microdevelopment (Thelen & Corbatta, 2002), which has been recently applied to language teaching by Pawlak and Mystkowska-Wiertelak (2015), can be very helpful in this regard. Then, too, MacIntyre's (2012) idiodynamic approach is an innovative method that addresses the need to make continuous observations within an instructional period. Both of these methods represent important developments in conducting research consonant with CDST; I return to a discussion of other research methods below.

Another important point, related to this need to consider a complex system's full history, is the misguided practice of wholly relying on randomized controlled trial experiments.

> We can no more "repeat" an experiment on a complex system than we can ask a class of fifth graders at the end of the school year to go back to the way they were at the beginning of the school year. However, the assumption in randomized controlled trial experiments is that the precise histories of systems are unimportant. (Ricca, 2012, p. 33)

Indeed, there was a great deal of consternation expressed recently (even in the media) about a study (Open Science Collaboration, 2015) that examined 100 replications in psychology. The study determined that a large portion of research studies that were replications found weaker evidence than the original findings. What distressed people was the assumption that if the research was valid, the results should replicate. When they found they did not, the questions then arose: Should the incongruence be blamed on the original research or on the replication, or is it the case that the findings are true only under certain conditions (Barrett, 2015)? Nevertheless, from a CDST perspective, discovering that findings from one study of human subjects do not obtain in a subsequent study is not surprising at all, given the situated nature of what is being studied. A related question along these same lines is whether it is reasonable and valid to assume that the treatments or interventions in controlled experiments are replicable in and of themselves. After all, treatments "are not implemented so much as enacted" (Clarke & QuinnWilliams, in press), and when it comes to classroom research, attempts to control all aspects in the enactment of an experimental intervention make the circumstances of the treatment artificial and ecologically suspect. This is especially so because a complex system is sensitive to its initial conditions. A different starting point will yield different results. This does not mean that we should avoid the kind of partial or reconceived or extended replication that Gass and Valmori (2015) call for. Indeed, Lowie (2015) opines that replication is very important. However, it does mean that we should

not expect that a replication will resolve a question once and for all. Research results should always be seen as provisional.

An additional problem attributable to the nonlinear behavior of complex systems is that it may be spurious on the basis of a simple experiment to claim that a particular experimental treatment works or does not work based on the difference between participants' scores on a pre-test and post-test. For one thing, it is certainly possible that the effect of an intervention does not occur within the timeframe of the design (Koopmans, 2014). Yet

> the assumptions underlying the use of [common] parametric Gaussian statistics – that the relationships under investigation are linear relations – is fundamentally challenged by recent studies that have used a dynamic perspective and which show the relationships between subsystems of a developing language system are nonlinear (de Bot, Lowie, & Verspoor, 2007; Larsen-Freeman & Cameron, 2008). (Lowie & Verspoor, 2015, p. 69)

On a related note, the assumption underlying a simple experiment is that any intervention is the cause of an outcome if it is statistically significant. This, too, is a problematic assumption. As I have argued, what is meaningful is not an intervention itself, but rather how individuals relate to it. "Of course, the real, observed effect is a combination of the intrinsic effect of the intervention and the effects of a number of uncontrolled variables that apply to a particular individual (van Geert & Steenbeek, 2014, p. 36).

A further problem lies in the recognition that the many components of a complex system are interconnected. Controlling all but one, which is what is done in a typical experimental study of a classroom intervention, ignores the fact that the one component has an effect on another component, often in unanticipated ways. All these are serious problems when it comes to classroom research using experimental designs. On top of these, there is the matter of the teacher's "emotional resistance to the new activities prescribed by the intervention" (van Geert & Steenbeek, 2014, p. 31). If teachers do not fully endorse the intervention, they are not likely to implement it as prescribed by the experimenter. While this has caused exasperation on the part of some researchers, it is the teacher's right, and some might say duty, to resist what is seen to be an inappropriate intervention.

Returning to Nuthall's point about focusing our research on individual students brings to mind a problem with sample-based research, which is that it allows generalizations at the level of the group, but it does not tell us much about the behavior of the individuals who comprise the group. Van Geert (2011) warns:

> . . . models based on aggregated data from individuals have no logical bearing on models of individual processes. Molenaar (2008) calls this the ergodicity principle.

> He and his collaborators have shown that the implicit step, so common in the behavioral sciences, from sample-based research to individual process statements is often demonstrably incorrect. (p. 275)

Nuthall (2004) advises that

> aggregation of data across students and across different learning outcomes must be carefully justified before it can be used. Individual students can have quite different experiences within the same classroom, begin with quite different background knowledge, and achieve significantly different outcomes (Nuthall, 1999a). Aggregation by summing test totals or class averages introduces unnecessary ambiguity and error. (p. 297)

This observation by Nuthall was certainly borne out in my study (Larsen-Freeman, 2006) of five Chinese learners enrolled in an English course over a 6-month period. When their performances were averaged, the learners appeared to make fairly uniform progress over the period. All the initial measures of complexity, accuracy, and fluency of their spoken and written English showed improvement by the end of the course, and most recorded steady improvement on the performance samples at regular intervals in between. However, by looking at the individual level of performance, it was clear that not all learners progressed evenly. In fact, some learners scored lower on certain measures at the end of the course than when they had started. The level of granularity at which the data were inspected made all the difference in whether or not progress was detected and the instruction deemed successful. Furthermore, as van Geert and Steenbeek put it (2014),

> the reason why intra- and inter-individual variability are in fact very different is that intra-individual variability results from the working of complex dynamic systems – such as an individual person in interaction with a particular educational environment – whereas inter-individual variability typically results from statistically constructed, simple additive systems. (p. 34)

Having up to this point been critical about classroom experiments that seek to establish a causal relationship between a particular practice and outcome, I should acknowledge that for certain constituencies, such as policy makers, a larger view may be warranted. For policy makers, "what matters is whether on the level of populations, the odds are in favor or not of a particular educational intervention, which is a matter of differences in averages" (van Geert & Steenbeek, 2014, p. 34).

So I do not deny that there is a place for educational research beyond the walls of the classroom. Indeed, "if we want to make statements about *general trends* of factors affecting products of development, then group generalizations

are useful, especially when applying Bayesian statistics and provided the focus is on power and effect sizes rather than on NHST [null hypothesis statistical testing]" (Lowie, 2015), the outcome of which is highly manipulable. For instance, it is well known that one can obtain statistically significant findings "because any size difference between groups (or correlation) will reach statistical significance given a large enough sample" (Plonsky, 2014, p. 464). However, I do not want to lose sight of the point that "the one thing that is known for certain is that the average is not good enough if the goal is to understand individuals: We must explain patterns of individual variability" (Rose, Rouhani, & Fischer, 2013, p. 152).

Recall, too, that complex systems are nested, which means that they are interconnected with other systems both at higher and lower levels than themselves. Thus, at this point in the article, readers may be forgiven for wondering just how researchers can truly meet all the expectations CDST asks of them. After all, if everything is connected with everything else, how can we adopt a perspective that does justice to the complex system that is the classroom in all its multiple embeddedness (Larsen-Freeman, in press)? One answer is to adopt one level as the focal level, which for present purposes may well be the classroom, but to interrogate the other nested levels of scale (Larsen-Freeman & Cameron, 2008). Indeed, whatever level of organization or subsystem is the focus of our research, we can always ask a series of key questions motivated by the perspective of complex systems. Here are a few suggested by Lemke and Sabelli (2008, p. 122):

- What next higher level of organization determines constraints on the dynamics at the focal level?
- How do all subsystems subject to those constraints interact to constitute the dynamics of the higher level?
- What degrees of freedom remain at the focal level after the constraints are allowed for?
- What units of analysis at the next level below interact to constitute units (or processes or patterns) at the focal level?
- What characteristics of those lower level units determine the range of dynamical possibilities at the focal level?

Another consideration is the reciprocal influence of each system or component of a system on the other (Kaneko, 2006), influences which provoke changes in both directions. We illustrated this reciprocity in our book (Larsen-Freeman & Cameron, 2008) from some research conducted by Cameron in an English language classroom in Norway. After recording all the interactions in a lesson, Cameron went on to calculate an "interaction differential." The interactional differential was a subjective measure of the difference between the lexicogrammatical and cognitive demands expected and the actual utterances. In

other words, the graph in Figure 1 taken from Larsen-Freeman and Cameron (2008, p. 210), in which the interactional differential is plotted, represents neither the teacher's nor the student's language. Rather, it is a collective variable which represents values pertaining to the difference between what the teacher's elicitations appear to expect and the learner's actual response. It is calculated by comparing the actual language used by the learner with the expected language as set up by the teacher's utterances.

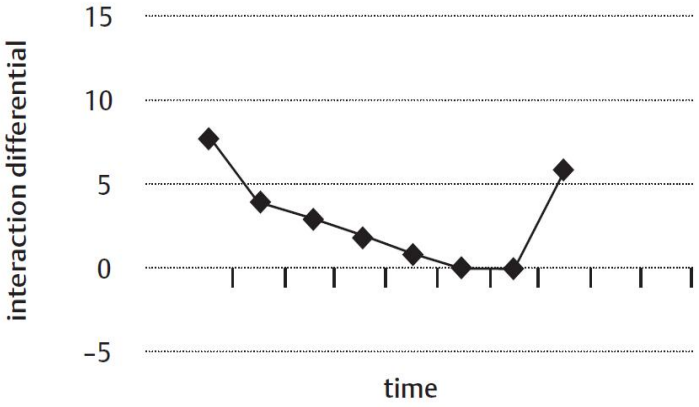

Figure 1 Trajectory of teacher interaction with learner A on the task, described in terms of the interaction differential (Larsen-Freeman & Cameron, 2008, p. 210)

As can be seen in Figure 1, there was a wide interactional difference to start with. The teacher's initial elicitation was an open request for information, but the student offered nothing in return. As the lesson preceded over time, teacher elicitations narrowed and were followed by limited responses from the student. The rise at the end of the exchange was due to concluding information given by the teacher. This concluding information increased in complexity and length. Thus, Figure 1 represents the overall trajectory of the interaction. This type of interaction has been termed *co-adaptation* by Larsen-Freeman and Cameron. Co-adaptation appears to be a particularly relevant type of change in the dynamic systems of the language classroom. Co-adaptation is change in connected systems, where change in one system or component of a system produces change in the other. Larsen-Freeman and Cameron (2008) further note that "language classrooms are full of people co-adapting – teacher with students, students with each other, teacher or students with learning contexts. Stabilized patterns of action, including language action, emerge from co-adaptation on various timescales" (p. 199).

Importantly, CDST is a systems theory. To help us understand a bit more what this means, here is my selective summary of an example from Mary Catherine

Bateson in her role supervising a counselor offered by Seltzer-Kelly et al. (as cited by Ricca, 2012).

> Mary Catherine Bateson reflects upon a videotaped family counseling session that she has watched repeatedly as part of her professional supervision of the counselor . . . The designated client is the child; however, over repeated viewings of the session, Bateson found that her perspective as to the actual source of the problem has shifted several times . . . Finally, she explains, she came to view the family dynamic in terms of Gregory Bateson's thought: to see the pathology as a product of the interaction of systems, rather than as residing in any individual. (p. 36)

A systems perspective is the reason why "to remove part of a complex system and isolate it for, say, 'closer study,' is to remove the 'pattern that connects' (Bateson, 1988)" (Ricca, 2012, p. 35). Indeed, conventional experiments can only, at best, lead to claims about proximate, linear causes, while not allowing for multiple or reciprocally interacting and nonlinear variables, which change over time and lead to emergent phenomena. "Likewise, a child taken from a classroom environment for assessment does not behave the same way as s/he does in a classroom and the attempt to understand the child's classroom behavior through such efforts is thwarted" (Ricca, 2012, p. 36). While I would not wish to discount experimental claims, I think that we do need to consider them carefully. As Horn (2008) remarks:

> In order to understand schools and classrooms as the complex environments that they are capable of becoming, we must first allow them to be so. This will require new methodologies . . . methodologies that do not reduce the phenomena studied to fit within the prevailing research repertoire . . . (p. 136)

3. Research methods for studying complex systems

So what classroom-oriented research methods are compatible with CDST? I have already mentioned *microdevelopment* and *idiodynamic approaches*. Other appropriate methods can be found in Dörnyei, MacIntyre and Henry's (2015) recent book on motivational dynamics and in Hiver and Al-Hoorie's (in press) call for a "dynamic ensemble." Social network analysis (Gallagher & Robins, 2015; Mercer, 2015) also shows promise. Gallagher and Robins (2015) explain,

> social scientists have generally operationalized groups in a way that is static and monolithic, such as through social categories, distinctions between types of language instruction, or in terms of experimentally designed groups. Consequently, in an attempt to move toward a view of language as a complex adaptive system, we should consider how to reapproach seminal, macrosocial concepts with new methods that elaborate on our understanding of group systems, as well as the interactions, situations, and encounters from which systems are constituted. (p. 931)

The newer approach involves statistical network modeling, which seeks to bridge the gap between individuals and the groups they are members of by constructing a network structure of the interaction.

To get the view of changes over time, longitudinal designs are essential (e.g., Ortega & Iberri-Shea, 2005; Pawlak, 2012). Then, of course, a richly contextual ethnography is especially useful in studying complex systems, where it is assumed that the observer is part of the system being observed. As Ricca (2012) remarks, "reflexivity in complex systems requires a different approach to study than the usual separation of observer and observed" (p. 37). Clarke and QuinnWilliams (in press) concur and add that "if we hope for our work as action researchers to have an impact on classroom practice, we must understand that we are part of the complex dynamic systems of school and classroom, not agents acting upon schools and classrooms." To this call for reflexive practice on the part of the researcher, Harvey (2015) adds this twist: ". . . I feel that if as a researcher I am to genuinely acknowledge the people I am working with as responsible agents of their own lives, I have a responsibility to give them the opportunity to theorize their own experience" (p. 24). For this reason, Harvey gave her analysis of the data to the participants in her study for them to comment upon. Beyond "member checking" to authenticate her interpretation, this step gave Harvey an important insight: "I became aware that her [one of her participants] story, and every participant's story, can never be finalized, and is always being reconstructed in a dialogic tension between the past and the present. The co-construction, therefore, continues" (p. 34).

Another limitation of conventional experiments occurs when researchers attempt to control context and situation, rather than investigating adaptation to the unique particularities of a context. A crucial characteristic of a complex system is its adaptability. A different type of experiment, described by Jacob (as cited in Reinking & Watkins, 2000) and called a *formative experiment*, focuses on the dynamics of implementation and might thus be capable of overcoming the limitations of a conventional experiment. According to Newman (as cited in Reinking & Watkins, 2000, p. 388), in a formative experiment, the researcher sets a pedagogical goal and finds out what it takes in terms of materials, organization, or changes in the intervention in order to reach the goal. In other words, once the goal is reached, the researcher can trace the adaptations that were made to get there.

Design-based research offers another alternative. A design-based researcher responds to the emergent features in the situation. A particular research angle is not adopted once and for all. After all, not all variables that turn out to be of interest are known in advance. Rather than creating research designs that isolate a single variable, design-based researchers examine multiple

dependent variables in order to develop a qualitative account that links different instructional conditions with different effects on learning, all the while acknowledging the complex social context of the classroom. Researchers adopt a retrodictive view, looking for the influence of prior activity on current activity (Larsen-Freeman, 2009). As Confrey (2006) writes, "such studies support views of the classroom not as deterministic, but as complex and conditional. In these settings, instructional guidance is based on affecting the likelihood of certain events and outcomes by adjusting the conditions of instruction" (p. 139).

Action research is concerned with possibility rather than prediction (Wadsworth, 1998). In keeping with the nature of complex systems, action research considers change and facilitates an examination of the emergent nature of change. As Ahmadian and Tavakoli (2011, p. 123) propose, in order for us to solve second language classroom problems, we need research traditions that are responsive to the unpredictability and dynamism of the behavior under investigation. The action of action research is what a teacher does to disrupt the equilibrium of the teaching and learning situation. Teachers are encouraged to challenge their assumptions by acting differently from their customary way of being in the classroom. In other words, teachers who practice action research are encouraged to introduce a perturbation into the system, to actively promote non-equilibrium. Then, after introducing noise, they watch what happens in order to inform their next move.

Finally, Burns and Knox (2011) write of their attempt at *relational model building*. While I suppose it would be incorrect to call model building a research method, it can nevertheless provide a platform for one. Their

> model conceptualizes the classroom not as a machine where inputs are processed and outputs generated, not as a space where activity takes place, . . . but as a convergence of different elements which stretch beyond the temporal and spatial location of a given classroom, and which combine in dynamic relationships. (p. 2)

In order to depict such dynamism, they built a relational model

> to be able to map interrelatedness, fluidity and unpredictability, rather than construct distinct, separate and fixed categories. (p. 5) . . . This model builds on, and extends existing classroom-based research in Applied Linguistics, and affords a relational view of the classroom in which there is no *a priori* start or end point; classrooms are convergences that reach backwards and forwards temporally, discursively, socially, cognitively, and culturally. (p. 19)

Although some might find these methods disappointing because of their inability to produce generalizable results, they should find reassurance in van Geert's

(2011) observation that case studies have significant theoretical import: "for students of language development, single case studies have a direct bearing on the underlying theory, and only an indirect one on the population of language learners . . ." (p. 276; see Larsen-Freeman, in press, for further discussion of the generalizability issue).

4. Conclusion

Kennedy (1999) concluded from her studies of teachers' thinking about research on teaching:

> The relationship between teaching and learning is the most central issue in teaching, and it is also the most perplexing and least understood. Teachers often feel that learning outcomes are unpredictable, mysterious and uncontrollable. It is not surprising to learn that teachers find studies most valuable when the studies give them a deeper understanding of this fundamental relationship. (p. 528)

I believe that CDST can contribute to this deeper understanding, an understanding informed by how the real world of the classroom operates, especially when our research agendas are informed by teachers' questions, when our research has ecological validity, which takes into account the complex reality of the classroom, and when findings are communicated in a straightforward and respectful manner, with the expectation of reciprocity (Larsen-Freeman, 2015). Nonetheless, seeing research findings as "applicable" to pedagogy might not be the way to think of them. In my opinion, perhaps the most important contribution of CDST-inspired research to effective teaching and learning is to challenge both researchers and teachers to think differently (Larsen-Freeman & Tedick, 2016) and to cultivate new ways of talking about what transpires in the classroom (Borg, 2010; Pedrazzini & Nava, 2012). I think that CDST offers a very useful way to conceptualize effective teaching and learning, to research it, and to stimulate conversations about enacting it.

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