PROMOTING EMERGENT UNDERSTANDING AND KNOWLEDGE: COMPUTER-MEDIATED COMMUNICATION FROM A COMPLEXITY THEORY PERSPECTIVE

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ABSTRACT

In this paper I focus on data taken from two different graduate seminars at the University of Arizona in which the classroom activities and curriculum have been meaningfully supported by the use of a computer-mediated learning environment. I analyze transcripts from postings made throughout both of the courses and relate this data to dynamic systems theory. I argue that the data supports the suggestion that computer-network based tools offer a useful communicative space for establishing and fostering interdependence and collaboration amongst students. In doing so the computer network also offers the possibility of capturing aspects of learning as a dynamic open system, the central idea in dynamic systems theory (also known as complexity or chaos theory) as discussed by Gleick (1988) and Larsen–Freeman (1997, 2002). This framework provides potentially useful ways of understanding the complex and non-linear aspects of learning as interactive social processes and practices.

INTRODUCTION

In this article, the meaning-making interactions of graduate students within a computer-mediated learning environment are described from a dynamic systems or complexity theory perspective. Focusing on learner interaction in this way involves a particular view of language, learning and the possibilities afforded by computer-networked learning systems. It involves thinking that is part of what Watson-Gegeo (2004) describes as the "paradigm shift in human and social sciences that is revolutionizing the way we view mind, language, epistemology and learning" (p.331). This shift, or social turn, in Applied Linguistics and Second Language Acquisition studies specifically is one to complement the mainstream SLA research that works within linear notions of cause and effect and of isolating and testing for variables that necessarily exclude issues of sociocultural context and the individuality and agency of the learner. A complexity theory approach allows the exploration and engagement with the multifaceted nature of interaction within any given learning situation and as such is broadly compatible with the ecological metaphor (Kramsch, 2002; van Lier, 2004) for language socialization as well as the growing body of work in sociocultural theory and language pedagogy (c.f. Lantolf, 1999 and 2000 for an overview and also Lantolf and Thorne, 2006). Hill (2003) for example, specifically draws comparisons with the non-

linear processes highlighted by complexity theory and the learning that takes place in the Vygotskian zone of proximal development. The commensurability of these two theoretical positions is however yet to be determined, though van Lier (2004) locates both theories within a broad ecological, semiotic perspective to language and education. Indeed, the application of this theory to Applied Linguistics in general has yet to be fully understood or developed, but the promise it holds for understanding what might be otherwise seen as anomalous learner interaction and behavior, both in and outside of the language classroom, means that it is surely worth pursuing.

In this paper I will apply some of the basic principles of dynamic systems theory to a small sample of data from two graduate-level classes that communicated extensively outside of the classroom, and discuss the insights and implications of this application. In both examples, small groups of graduate students, both Native and Non-native English speakers, met for two and a half hour sessions, once a week, in a classroom developed for network-based interaction. The learners and instructor also made considerable use of the WebCT® system that allowed for asynchronous discussions to be threaded and continued throughout the 16-week semester. Students were encouraged to discuss theoretical issues arising during class discussions or readings, and also manage the class-based collaborative work that was an important component of this course.

COMPUTER-MEDIATED COMMUNICATION

As Thorne and Payne (2005) point out in their recent review of the language learning and technology field, a third generation of computer usage in language teaching and learning is now a reality. The most recent trends are currently towards what is termed *device-agnostic CMC,* involving a clear shift away from the time when technology was seen as a useful device primarily for language drilling for specific skills-based practice. Computer-mediated communication may be broadly defined as the use of computers and computer networks for communication purposes. Synchronous and asynchronous forms include chat, e-mail, Wikis and discussion-based message boards. Warschauer and Kern (2000) suggest that the potential for offering new kinds of communication that these tools provide are shaping different ways of communicating and learning: “These new technologies do not only serve the new teaching/learning paradigms, they also help shape the new paradigms. The very existence of networked computers creates possibilities for new kinds of communication” (p.12). Thinking about CMC from an ecological perspective allows us to see these learning media as offering different *affordances* for learning. The idea of affordances is useful here and is defined by van Lier as “a relationship between an organism (a learner in our case) and the environment, that signals an opportunity for or inhibition of action” (van Lier, 2004, p.4). The affordances of the CMC environment potentially include new ways for students to collaborate and co-construct knowledge and meaning, presenting as they do a space where “access is available and

engagement encouraged" (van Lier, 2000, p. 253).

This technological move towards network-based learning is perhaps a part of larger developments in the workplace and in communication on a societal and even a global level. Indeed, as the world becomes increasingly global in nature, to some extent based on the new literacies of technology and information, there is a risk that the world is eventually going to become divided between those who have access to this domain and those who do not. Gee (2000, p. 43) describes this technological revolution as the "new Fordism" in terms of how it has changed global capitalism. We have gone beyond the old production capitalism into the information-based capitalism that makes very different demands on the citizens under its employ. It is suggested that economic marginality awaits those who do not fit in with the new ways of thinking and operating that characterize the new global capitalism which is now increasingly based on networked and socially situated ways of thinking and operating. It is a system demanding ever-increasing flexibility and new ways of interacting with information and technology from participants. It follows then that it is important that education keep ahead of these changes in the broader society - regardless of reservations educators may have about the ways in which technology is changing the world around us.

In this study, technology, in the form of asynchronous message boards, was purposely employed by the class instructor, to try to re-shape the ways that students interacted and collaborated, in keeping with the stated objectives of the class which were to create, explore and further collaboration and interdependent learning amongst the participants. As this was an explicit and specific goal of this graduate level seminar (Wildner–Basset, 2002), very much within the paradigm shift mentioned earlier, it is worthwhile to consider the role that the computer-mediated communication played in the realization of this goal.

COMPLEXITY THEORY

In rejecting the idea of learning as a simple cause and effect process with tokens of knowledge being passed from one who knows to those who do not, we must simultaneously embrace an alternate view. In this I follow the lead given by Larson- Freeman (1997, 2002) Leather and van Dam (2002), van Lier (2000, 2002, 2004), and Wildner-Basset (2005) in applying the theoretical understanding provided by complexity theory to allow educators interested in learner discourse to further understand the dynamic ways in which learners interact and create meaning for themselves and each other. van Lier (2004) makes this application explicit:

> Within an ecosystem, including any social ecosystem (a family, a classroom, a school) a large number of influences are present in a partially chaotic, unpredictable and uncontrolled way…a complex order emerges…is dynamic rather than static and provides affordances for active participants. Learning emerges as part of the affordances being picked up for further action (p. 8).

The ideas behind complexity theory came to the public consciousness in two bestselling works that detailed the possibilities being offered by developments in scientific thought and inquiry. These were Gleick's (1987) *Chaos: towards a new kind of Science* and Waldrop's (1992) *Complexity: the emerging science at the edge of order and chaos*. These ideas were first related to Applied Linguistics in the influential work of Larsen-Freeman (1997, 2002), and have since been developed by other research in language education (Hill, 2002, Cameron, 2003 and Mallows, 2003). These ideas seem to have resonated elsewhere in research on development and cognition. Bates and Thelen (2003), make a case for linking connectionist theories of mind with dynamic systems theory. Similarly, Garson (1998) investigates ways in which the brain's function is best understood by and is dependent upon the functioning of a dynamic system. Larsen-Freeman (2000) describes language itself as a dynamic system made up of many elements such as syntax, morphology, phonology etc., interacting together through use over time in non-linear and unpredictable ways and producing diachronic change and variation. This led Larsen-Freeman to coin the term "grammaring" (1991) as a way to try to capture this dynamic nature of language in use. Cameron (2003) looks at the way in which discourse is created from such interacting elements of use and concludes that language at the discoursal level can be seen as a dynamic system and that discoursal features such as metaphor may be better explained by considering them as *attractors* (an attractor is a set to which the system evolves after a sufficient period of time.) Indeed there is a growing interest in many fields in the applications for research that this 'new science' offers. The basic tenets of complexity theory were outlined by Larsen-Freeman (1997) and this offers a useful framework for understanding and application (see also van Lier, 2004 for an overview of the theory and applications for language pedagogy and learning.) I will now sketch the main features of this theory and subsequently apply these to the research context with which I am concerned.

Dynamic, Complex, Non-Linear

Complex systems are defined as being made up of many, often diverse, components that interact together over time. The components react to the environment and to each other, meaning that even in a state of equilibrium, the system is never fixed or fully static. Order within the system emerges out of these interactions in cyclical shifts of energy and activity that may take the system towards what is referred to as the edge of chaos. It is at these moments that restructuring in the dynamics of the system will occur. The shifts in

energy can be triggered by seemingly insignificant changes in the environment whereas what might be taken as a massive trigger within such a system may have little or no effect at all. This aspect of the systems is well known as the 'butterfly effect'. This is the reason, for example, that the weather is notoriously difficult to predict, since minute shifts in the conditions can have dramatic consequences when magnified through further changes as they develop over time.

Chaotic, Unpredictable, Sensitive to Initial Conditions

The chaotic and unpredictable nature of a dynamic system is seen within the dynamic interaction over time that defines it. That change will occur is certain but it is impossible to predict when and why these transformations will occur. An example of this, often cited, is the movement of a tiny pebble on a mountainside triggering an avalanche. That the avalanche was coming was not in doubt but when exactly it was to be triggered was uncertain and the smallest movement of one component within the overall system ultimately produced it. The avalanche itself, incidentally, can be seen as a restructuring of the system of the mountain and its immediate ecology. The term "initial conditions" refers to the components of the system and how they relate to each other and the environment. The effects of their relationship will be magnified as interactions take place over time, and large divergences may appear from what were initially very small differences. In terms of pedagogy it is useful to think about the fact that no two lessons ever seem to unfold in the same way. A lesson plan that worked brilliantly the previous semester may suddenly appear to be simply not effective. This change in outcomes can be explained by a change in the initial conditions of the lesson – different students and perhaps even factors such as the time of the class may be important.

Open, Self-Organizing, Feedback-Sensitive, Adaptive

A dynamic system is said to be open because it must by definition be receiving energy from the environment within which it exists. If the system is closed and cut off from the environment it will cease to be. Because the elements of the system are located within a larger system and not merely haphazardly interacting, they will self-organize to maintain that system. There are boundaries and rules as to what can happen in that system, so to expand on the weather example already discussed, there are an infinite number of variations within the different types of weather possible, but that they fall within the attractor of a climate, so the attractor state is confined within the climactic system. The order and restructurings that do exist are due to the fact that the system is feedback sensitive, which means that there is always going to be an element of unpredictability and instability present. "Positive feedback kicks evolution forward" as Briggs (cited in Larsen-Freeman, 1997, p.145) explains. If the evolutionary patterns of species, for further example, are dynamic, complex systems as suggested, then the two poles of positive and negative feedback are what drive the process forward. The species are then

seen as not merely passively responding to their environment but also interacting with it to produce the best and most advantageous outcomes – in other words self-organizing through feedback from interaction. To return to the classroom example, the dynamics of any classroom will necessarily change through the course of a lesson period, a week and a semester, as the different participants interact in multiple ways. Teachers often talk informally about a class that has turned into a difficult one to teach after some unexpected event or interaction that has taken place. This change in classroom functioning is of course impossible to predict and account for and yet may have serious implications for the learning that takes place.

Strange Attractors, Fractal Shape

"The path that a dynamic system takes can be traced in space and is called an attractor" (Larsen-Freeman, 1997, p.145). The attractors or paths in dynamic systems are called *strange* because of their unpredictable and non-linear nature. The tracing of the dynamic system paths for the data in this paper takes the form of a simple graph, which highlights the ebb and flow of student interactions over time throughout a semester (see figures 1 and 2). For every class such a path would, of course, be different as the interactants self-organize and interact with their environments and each other. The term *fractal* refers to the idea of self-similarity at different magnification within a system. Agar (2005) cites the example of the stock market to highlight this phenomenon. When taken over a year, the fluctuations of any given market will give rise to a certain pattern when charted through time on a graph. These patterns ca be reflected at different time scales from a month, week, day, and even down to the hour. The important point of this self-similarity to the theory is that it suggests continuous dynamism within the system; even when it appears to be static, magnification to some degree will reveal activity and change.

COMPLEXITY AND A CMC LEARNING ENVIRONMENT

In this study I am interested in the dynamic ongoing cycles of the learners within the CMC system. The notions of stability, instability, open-system, and chaos match to a great degree the fluctuations of creativity and interaction within a classroom and CMC environment. The idea that the system shifts, breaks down and restructures itself on a different plane also seems to capture something of the essence in what happens when groups of learners come together and try to work together in perhaps ways that are unfamiliar to them. The paradigm shift necessary to create true collaboration and interdependence amongst learners was the key element in providing the framework for interaction in this instance, and the WEBCT® system provided the tool to enable this shift. The rest was up to the learners and instructor to negotiate and navigate as the semester unfolded. In the following table the central notions of dynamic systems theory as outlined above, have been applied to a CMC classroom environment:

Table 1. Complexity Theory and CMC. (Adapted from Larsen-Freeman, 1997a)

Features Of A Complex, Dynamic System	**Applied To Interaction And Learning In A CMC Environment**
Sensitive to Initial Conditions	Student identities, needs, trajectories. Syllabus. Materials.Context etc. Necessarily different for each class
Dynamic, Open	System evolves over the semester as individual students interact with their learning environment and initial conditions
Complex, Emergent	Composed of many diverse individuals that interact in non-linear and unpredictable ways. Resistance can be seen as chaotic turbulence out of which new order may emerge
Self-Organizing Adaptive	Shifts in behavior in student learning and interaction patterns will occur throughout the semester
Feedback Sensitive	The members of the class also belong simultaneously to many other systems and will bring their ideas and suggestions into the system as it progresses. The Instructor may also provide 'feedback' in the traditional understanding
Strange Attractors	The path that the class postings/discussions and learning takes through the semester is not predictable
Fractal	Levels of interaction and activity within the system will be reflected at different time scales throughout the semester of participation. The similar patterns that emerge suggest continuous shifts and dynamism

As mentioned above, the initial conditions of any class are necessarily complex and unique. Student identities, how they identify themselves and are identified by discourse within a class will of course be multiple and changing over time, depending upon how the students relate to the course itself, their peers and instructor and sense of self. Identity will necessarily intersect with the evolving *trajectories* of the students also. Trajectory is a notion developed by Lave and Wenger (1991), and attempts to capture the dynamic nature of participant engagement with a community and is dependent upon a range of factors. For example, if a student perceives a given class that they take as

either crucial to their development or as simply a filler class for credit, this is obviously going to have a large bearing on how that student will respond in that class. These are, in a sense, hidden variables and yet consideration of their impact allows us to see the truly multifaceted nature of teaching of any kind.

The idea of the fractal in which levels of interaction are repeated at different levels, and on different scales, throughout a system is a more difficult notion to apply to a class situation. It could be, for example, that as energy within the class shifts, that patterns of interaction inside the classroom at the more micro-level of group discussion, are reflected in the class as a whole; or indeed the patterns of interaction within the CMC modality. As will be touched on below, the way in which different aspects of the learning ecology complement and re-enforce each other, or not, is certainly an interesting area for further research in exploring the dynamics of pedagogical practice and outcomes.

I suggest then that the dynamic system theoretical perspective outlined offers a different and potentially useful perspective on learner interaction. This perspective locates the learner within their full social situation and further sees the participants as individuals with complex and changing needs and wants within the classroom context. The central question with which I approach the data from the WebCT® learning environment is: What *restructuring* of interaction and outcomes emerge in the postings of a group of learners as they come together and interact in a specific context?

THE RESEARCH CONTEXT

The data to be examined in this paper are taken from the asynchronous WebCT® postings from two graduate-level courses in the Second Language Acquisition and Teaching program at the University of Arizona. WebCT® offers an online web space, organized by the instructor, that allows for the posting of syllabi, synchronous chat, grade updates, and asynchronous, threaded discussion boards. Dr. Mary Wildner-Basset taught both of these classes in the COHLab, which is both a physical facility and a theoretical, research- based project developed in the College of Humanities at the University of Arizona. A full description of the COHLab and its functions and operations can be found in Wildner-Basset (2002) and McBride (2005). The title of the course was in both instances “Pedagogy of Cultural Change: Non-foundational Paradigms and CMC in Real Life Classrooms”. The students were all at the graduate level and were either Native Speakers of English or else highly proficient Non-native Speakers of English. The classes were small, 6 students in class 1, which took place in the fall of 2002, and 5 students in class 2 which convened in the spring of 2004. The classes met for two and a half hours once a week for 16 weeks and students were encouraged to use the WEBCT® class site to collaborate and discuss with their fellow students and instructor. The majority of the postings detailed were made outside of class time but postings and activities were also recorded in class

time such as a weekly "one minute reflection" at the end of each class. The goal of the class as described on the syllabus was to "think and live beyond the constraints of the still dominant cultures of the classroom and of its related research to create new communities of knowing" (Wildner-Basset, General Rationale). In other words, the students were asked to simultaneously theorize and study about different ways of learning and being within a computer-mediated communication framework in an educational context as well as to *live* the paradigm shift towards collaborative, constructivist approaches in their own activity as students.

THE DATA

A complexity theory perspective provides the opportunity to think about classroom interactions in several ways. At the micro level we may be concerned with the details of how the interactions are operating to create new knowledge and understandings or what Mercer (1999) has termed "the guided construction of knowledge" (p.9). At the macro level we can also take interest in the general ways in which the system organizes, structures, and changes itself over time. For this reason, the data from the two discussion boards was firstly looked at in terms of basic number of contributions over time. These have been plotted in figures 1 and 2 below. The calculation of the graph data takes no account of the length of the posting, or its nature or whether it was posted inside or outside of class time. The majority of the postings were made outside of class time. The idea was simply to try to capture the dynamics of the energy within the systems as the learners progressed through the semester. The resultant graphs (fig. 1 and 2) offer a very general insight into ways that the students were engaged in different ways at different times throughout the semester. In terms of complexity theory, I have then drawn an *attractor,* or path, for each dynamic system as outlined above. Once these general trends were established it was hypothesized that it would then be insightful to look at the micro-level interactions at different points within the timeline of the semester to try to evaluate what was happening within the system when the sudden shifts in activity appeared to be taking place. So, for example, in the first class it is interesting to analyze what happens to create the large spikes in activity that take place in weeks two and three. Similarly in the second set of data, around week eleven, there appears to be a sudden and dramatic shift in activity after a period of relative inactivity in the preceding weeks. The data from both of these classes (in Table 2 and Table 3 below) have therefore been transcribed for analysis in terms of the dynamic systems theoretical perspective to see what insights may be gained from these very moments in the semester. The interactions in both cases appeared within three day time periods of the point indicated by the arrow on the graphs. The names of the participants have been changed and prior consent was obtained as part of the COHLab project.

Figure 1. Graph Showing the Path of Classroom Interaction for Class One. Fall 2002.

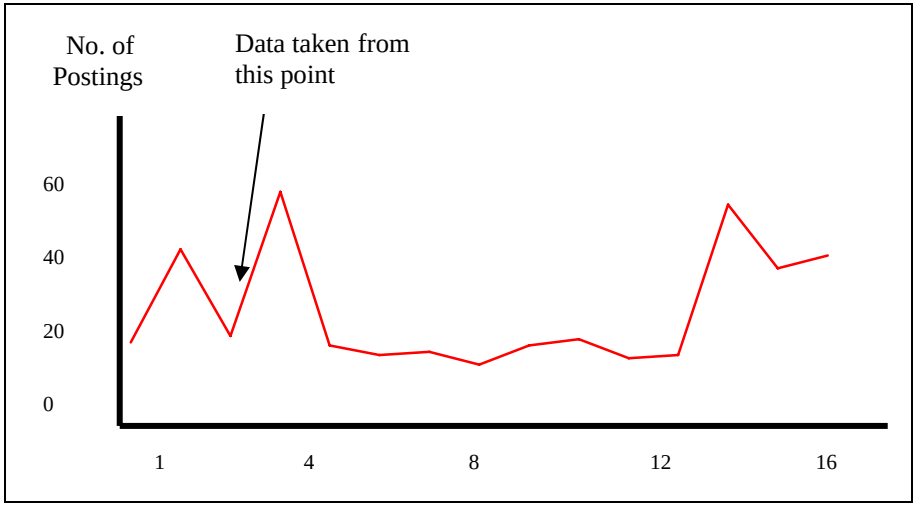

Figure 2. Graph Showing the Path of Classroom Interaction for Class 2. Spring 2004.

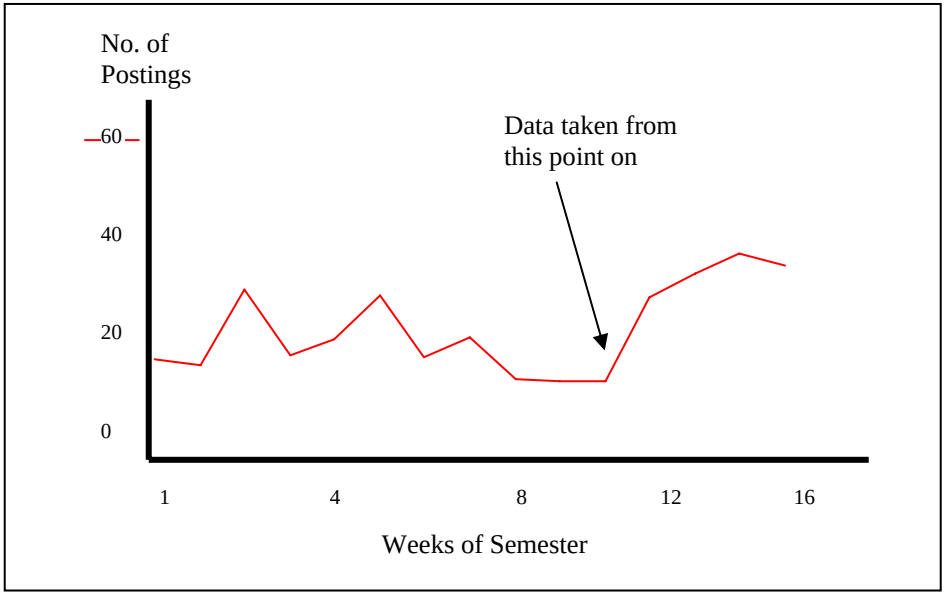

Table 2. Example of Asynchronous Web Postings for Class One

	CLASS 1. WEBCT® Postings between Monday and Thursday – Week 3
Posting 1	**Laura**: he successfully finished the activity and got to know what he was supposed to do and how to organize his language on the tacit ground
Posting 2	**Lena**: This just feels strange at the moment because I learned "tacit" as a new word just the day before yesterday and memorized it as "something, which cannot be described". Ok. Let's describe something that cannot be described and I am not quite sure I get it…
Posting 3	**Petra**: Tacit knowledge is unspoken knowledge. Tacit knowledge would be assumptions that we carry on a topic such as language learning and teaching. An assumption that I carry (and I'm not sure if I'm answering this question correctly) about learning and teaching is that it is important to have a student-centered environment…that student centeredness is "good" it is "the best way". And this has been a big part of my belief system.
Posting 4	**John**: Tacit knowledge, I'm really not sure I have a complete grasp of what this type of knowledge entails. I think part of my problem is that I have contradictory notions of what "knowledge" is. A part of me views it as a collection of facts, while another part of me sees it as a process.
Posting 5	**Laura**: I think knowledge is both a process and knowing about facts. It is just that the "knowing of facts" develops or changes over the course of time (either because of experience, as in Petra's case or because of you acquiring more facts and thus shaping your knowledge and this development of the "knowing of facts" of course happens as a process.
Posting 6	**Katrina**: Two examples of tacit knowledge for me are: the role of grammar teaching and critical period hypothesis. The first example is probably the more interesting, for I have changed my mind on it several different times in the past 5 years...
Posting 7	**Instructor**: I think you do indeed grasp the meaning of tacit. Literally, it means "silent". So silent knowledge or assumptions, in this context, would be what is working in us but never mentioned or spoken about. It is also, thus, hard to describe.

Interaction Analysis and Discussion of Class 1 Postings

This section of postings starts with Lena, in posting 1, mentioning the word "tacit" in her in class posting. As it happens, Laura (posting 2) does not fully understand this term that has been used and so is able to seek clarification on the discussion board. This triggers a series of postings in discussion to co-create an understanding of this term within the context of the class. It is noticeable that the class members do this by making sense of their own experiences as teachers and learners through shared personal narrative. Further discussion, elaboration and collaboration ensue in the postings and ultimately involves each member of the class as discussion moves to different kinds of knowledge related to the notion of tacit knowledge, feedback and clarification (postings 4-7). What is interesting from a dynamic systems perspective is the way in which this interaction occurs in a specifically "non-linear" and unpredictable way. By this I mean that there are sudden changes in the interaction both in terms of amount of interaction and also in the depth of discussion. The one almost casual question at the end of a routine message causes a surge in activity within the system and is responsible for generating what we can assume is meaningful interaction and a collaborative exploration of meaning within the group. As van Lier (2004) has stated, "Learning emerges as part of the affordances being picked up for further action" (p.8), and this notion seems to be borne out by the example here in which the web postings themselves become a part of the learning ecology of the class offering the students opportunity for further action and development.The use of personal narrative has been demonstrated to be one of the most important ways in which people make sense of their own experience (Polkinghorne, 1988), and the use of such narratives in this context suggests a high level of personal involvement and engagement from the participants. This is also a very good example of an affordance provided by the ecology of the learning environment within which the students are interacting.

Table 3. Example of Asynchronous Web Postings for Class Two

	CLASS 2. WEBCT® Postings between Monday and Thursday – week 11
Posting 1	**Tom**: Well, I guess I give up! I suppose I'll write up my research as a paper and hand that in and present the paper on the final day of class
Posting 2	**Jane**: Yeah, I was thinking the same - if there's nothing else posted after returning from TESOL, I give up.
Posting 3	**Instructor**: The main feeling I get, just to be frank, from the overall interaction in the group this semester, and especially on CMC discussions, is that of most everyone taking the path of least resistance most of the time…

Posting 4	**Tom**: I felt like giving up when I got back from TESOL because the silence in the WebCT felt to me like active resistance to the process. I just felt that coerced co-construction is no co-construction at all
Posting 5	**Emily:** The situation in our class in getting from pleasant to very NEGATIVE Tom and Instructor are getting frustrated whereas I don't feel that way at all... I certainly am not rebelling… I guess I sound irritated, but I'm not that irritated, I just think we could have done this faster and in one shot in class, unless we had so many other things planned for in class that we had to co-construct out of class. I hope I or anybody else doesn't resort to being this confrontational again—it is unacceptable, computer-mediated or not.
Posting 6	**Emily:** I find it fascinating how differently people perceive this class. And Tom, if you were that frustrated, you could have also sent me an email and told me to get my act together and respond on the WebCT. Don't assume that I'm rebelling. I would have done so gladly. I honestly misunderstood the class agenda. I'm sorry.
Posting 7	**Tom:** Well...I said it felt like you were resisting – an unfair assumption based on a misunderstanding – I accept that. But that is what it felt like. I didn't send an email because it hardly seems my place to do so and as I say - having to ask people to contributes defeats the purpose pretty much.
Posting 8	**Jane**: Although this all sounds negative, it is not a reflection on anyone. I like and respect everyone involved in this class. Everyone has made great contributions--I just wish there was more of that!
Posting 9	**Instructor:** I'm in fact right now feeling better about some aspects of our class than I have all semester. At least there's some stuff happening.
Posting 10	**Jane:** HEY EVERYONE! I don't think this is so hard--we just have to get to it. We need to co-construct our final assessment activity and we have a good idea, but all we've done so far is talk around it an not get into the meat of it. So here goes:

Interaction Analysis and Discussion of Class 2 Postings

The second data example is taken from postings at around week twelve of the semester in the second class. What is interesting to note in the graph (figure 2) above is the fact that prior to the postings seen in this example, the number of postings has fallen to almost nothing for a number of weeks. This cycle is broken by the announcements from Tom and Jane in Postings 1 and 2 that they are "giving up" in trying to collaborate with their classmates and that they feel their time will be better spent working individually on their own projects. A clear sense of frustration is evident in

these postings. The frustration triggers a response from the Instructor (posting 3) who is also clearly frustrated by the lack of activity and progress within the group and she expresses her frustration with the thought that perhaps the students are only "taking the path of least resistance most of the time…" This suggestion brings further response from Tom (posting 4) and then a more heated response from Emily (posting 5) who feels that the tone of the class discussion is becoming "unacceptable". More discussion and analysis follows until it seems at one point in the postings that the class may have experienced a serious breakdown in communication and collaboration.

A complexity theory perspective suggests that what the group experienced was a shift away from equilibrium within the system. The lack of activity and perceived resistance to the project generated energy within the system that rapidly transformed into a strain on the class dynamics as the shift away from equilibrium and balance continued. The turbulence that was felt can be seen as a move towards the turbulent edge of chaos at which point the system would surely break down. However it is interesting to note that in fact what happens is that the system self-corrects and re-organizes. This can be seen in Jane's final message in this example (posting 10), where she calls upon her classmates to renew their efforts at collaborative enterprise. Indeed this can be seen as a transition and restructuring of the class dynamics as following on from this interaction, the activity within the system is seen at its most intense and is sustained for the rest of the 16 week semester and culminates in a successful completion of the term project. The system was indeed sensitive to feedback from the environment and the turbulence experienced might be seen as a phase that had to be gone through to achieve the requisite level of interaction and succeed in truly co-operative and collaborative learning in this class. As Leather suggests, "this area of equipoise between stability and instability is where creative reorganization is evinced" (2002, p. 60). This is also evidence of what Thorne (2003) describes as "emergent interpersonal dynamics" (p. 1), and suggests that learning to learn in an unfamiliar paradigm requires students to renegotiate the participation structures of the class and the ways of interacting and operating within that class.

FURTHER IMPLICATIONS AND CONCLUSION

It has to be recognized that the data samples here are small and taken from specialized classroom situations. Graduate students in small seminar settings may not offer a good example for what typically happens in general educational practice. Similarly the classes here contained native speakers and very high-level non-native speakers who are in graduate programs in the United States. Again, hardly a typical population from which to draw firm conclusions regarding language use in classroom behavior. Given these limitations however I still feel these examples offer us insight into the ways that a computer network-based approach can complement and improve classroom instruction.

One important focus of L2 research has, for example, been the extent to which CMC creates more favorable participation opportunities for students

compared with traditional classroom settings. There is interest in the role of CMC as a possible 'equalizer' in participation (Hansen, 2005) that allows for greater participation by less active students, and changes the traditional teacher-dominated discussion structure (Honeycutt, 2001). Warschauer (1996) for example concluded, "that electronic discussion may create opportunities for more equal participation in the classroom" (p. 36). This additional space for discussion means that all students, and especially underrepresented or less active students, are given opportunity to interact and learn. There is evidence in the small samples in this study that the role of the teacher in these computer-mediated discussions is one of equal participant and that the technology affords students the opportunity to determine the course of the discussion. For example, in the case in Class One, Posting 2, above, we see Lena taking responsibility to explore an issue from something that has arisen in the classroom discussion. This leads to a significant, student lead, interaction involving the class and finally the instructor. Other studies, e.g. (Liu and Sadler, 2002; Kern, 1995) have proposed that a hybrid use of face-to face and CMC communication may provide the most effective learning environment, in the case of Liu and Sadler's study, for peer review work with L2 writers. This is a suggestion that is partly supported by these findings, again by evidence that ideas arising from the face-to-face interaction are later taken and discussed in detail in the asynchronous mode. The relationship between classroom interaction and CMC work, and ways that they may complement and support each other is crucial to understanding the pedagogic value of CMC and should be the subject of further research.

What these two examples also suggest is that an online computer-mediated discussion board can harness the energies and engagements of learners in meaningful and constructive ways. The two small examples show us that essentially capturing such energy can create a dynamic complex system that will evolve organically over time and can deepen the learning experience and sense of community for a class. As instructors and learners, we have all experienced a class situation where once the lesson has ended; the energy created within the class time dissipates as books are being placed into bags and the students head for the door. The high level of interaction and instances of collaborative learning evidenced in the discussion posts for both of these classes suggest that the use of such a learning tool can effectively combat such a scenario.

However, as Hansen (2005) warns, CMC cannot be seen as an all-powerful mode of communication that will, in and of itself, lead to more powerful learning outcomes. Indeed one of the perhaps contradictory findings of the small samples provided here (see also Wildner-Basset, 2002), is that students may well resist the CMC participation and the extra work and commitment that collaboration of this nature can entail. By looking longitudinally at the interaction patterns over a semester it is possible to see that investment and activity within the system are not always apparent and therefore the CMC environment cannot be said to be functioning effectively throughout the semester. Indeed, in figure 1 above, between weeks 4 and 12

there appears to be very little use made of the discussion board at all. This is eventually reflected in the apparent frustration of some of the class members and instructor (Table 3, postings 5 and 7). A complexity theory perspective allows us to see these ebbs and flows as a natural progression within a learning system – in which the possibility that the system may simply lose energy and die out is also a real possibility. The theory tells us that the system requires 'energy', attention and effort on behalf of the instructor and students if it is to develop and the benefits of the further interaction are to be realized. The notion of the *strange attractors* (see table 1*)* within the theory suggests that the path taken by any class will necessarily be different and unpredictable – given the different *initial conditions* that will form any classroom ecology. This provides further evidence then that CMC technology cannot simply be employed without due care and consideration for pedagogical practice.

The data also supports the claim from within a dynamic systems theory of learning that the learning process is not a linear transmission of knowledge from an expert to a novice. As Mercer helpfully reminds us, "The essence of human knowledge and understanding is that it is shared…[and it] is rarely, if ever, a matter of simply pooling information…knowledge and understanding are only generated by working with information, selecting from it, organizing it, arguing for its relevance" (1995, p. 67). The unpredictable nature of the learning experiences seen in these examples points to the suggestion made above that in a non-linear dynamic system, large re-structuring can be caused by the smallest of interactions or interventions within the system. Learning then can be usefully characterized as a process and not simply an end product, or as Gleick put it: "…of becoming rather than being" (p. 5). The examples offer evidence of the notion from van Lier (2004) that indeed teaching does not *cause* learning, at least not in the lockstep, linear ways suggested by the notions of input and output and resulting approaches to language curricula. This may seem counterintuitive, but recognition of this fact surely allows for teachers to stop trying to *force* learners to learn and allows them to concentrate instead on providing the basis for meaningful activity and affordance within a rich learning environment. It also speaks to the experience of many educators who, in conversation about their work, will often express frustration when students just aren't "getting it" and likewise joy for those unexpected and perhaps unplanned for "A-ha!" moments that learners may experience from time to time. This approach allows us to make sense of such everyday phenomena in our classrooms. Similarly, resistance and turbulence within a class system can be a positive energy for change and ought to be embraced (so long as it doesn't descend into flaming or abuse) rather than suppressed by educators. When embraced in a constructive way, such resistance as we have seen in the example above can lead to creativity and enhanced possibilities for learning and progress. The concluding point of this paper is perhaps best expressed by Lantolf and Genung (2000):

> Proponents of these theories suggest that effective learning and motivation are always socially embedded...as will become clear,

> ineffective learning is also socially embedded. It is not embedding that makes learning effective; it is the quality of the social framework and the activity carried out within that framework that determine learning outcomes (p.176).

The suggestion of the data discussed in this paper is then that computer-mediated communication is one way of potentially providing the kind of quality social learning framework within which learners may carry out meaningful and effective learning activity. Evidence to support this claim can be seen in the engagement and participation by students, that is, I would argue, reflected in the online postings within the semesters in question. At times the postings cited became very personal and there was evidence of tension, friction and turbulence, all of which speaks of involvement and investment on behalf of the students.

In conclusion, the dynamic systems theoretical framework allows us to understand the CMC data in ways that may not have been possible before. Specifically, the theory suggests the value of looking at specific classroom communication as part of a whole system of interactions. Periods of inactivity followed by sudden bursts of creativity no longer seem anomalous and seemingly innocuous questions that produce detailed discussion and feedback can be understood as integral parts of a functioning system. In considering the different and complex elements that can impact and influence learners and learning outcomes "in relational terms" (Larsen-Freeman, 2002,p.44), as participants engage in real world contexts, we gain a fresh perspective on the potential for computer networks to enhance and complement the goals of classroom teaching.

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