

## Non-linear Dynamical Development of CSCL Communities

Li Sha

Faculty of Education  
Simon Fraser University  
lsha@sfu.ca

Jan van Aalst

Faculty of Education  
Simon Fraser University  
vanaalst@sfu.ca

**Abstract.** The goal of this study was to explore the dynamics of the formation and development of CSCL communities, which is believed to reflect, to a large extent, the interaction among learners. Two different types of CSCL communities (grade four students and teacher education) were investigated. The data representing note reading were analyzed from a non-linear dynamical system perspective. The findings indicate that the grade four data are best described by an exponential model, and the teacher education data by an oscillatory model. We conclude that the method we discuss is potentially useful for understanding the development of reading practices in a CSCL community.

**Keywords:** Knowledge building, development, non-linear dynamical system

### INTRODUCTION

The notion of a learning community has received much attention in recent years, especially in research on CSCL (Brown & Campione, 1990; Lock, 2002; Scardamalia, 2002; Woodruff, 1999). Researchers in CSCL may be interested in how an online learning community develops over time. Factors influencing this development include the task assigned the teachers' interventions. Another question is how the development of the learning community influences individual and collective learning outcomes. Such issues can be investigated empirically. For instance, Hewitt (2003) investigated the development of threads that reflects the interactions among online learners in terms of idea exchange. According to Hewitt, "Online interaction is dynamic and its development is shaped by a wide variety of factors" (p. 32). Those factors include, for instance, the needs and goals of the participants, the requirements of the course the instructor defines (i.e. the invention imposed by the instructor), the role of the instructor, and the emergent properties of the discourse itself (Hewitt, 2003). In other words, the evolution of a learning community is inextricably bound to the setting in which the discussion takes place.

In the case of knowledge building, a specific approach in CSCL, Bereiter (2002) has pointed out the importance of *emergence*. Since nonlinear dynamical models have had some success in explaining emergent phenomena in a number of fields (Guastello, 2002; Morrison, 2002), our research program examines its use for explaining how learning communities—strictly speaking, knowledge building communities—develop. As a first step in this direction, this study examines the trajectories of one variable, *note reading*, in a relatively large set of online discussions in Knowledge Forum™. Follow-up studies will extend the picture we can develop to other variables including variables from social network theory (Haythornthwaite, 2002).

Stahl (2000) posits collaborative knowledge building as a social process of interacting with others, and involving the interplay of group and personal perspectives. Knowledge that can be considered a product of social communication is embedded in the interaction patterns of the communicating societies. In Stahl's study, the learning process is modeled as the mutual constitution of the individual and the social. Knowledge is a socially mediated product.

A CSCL community can be conceived of as a social network in which students are seen as nodes, and the interplays between them occurring in collaborative interactions are treated as social relations (Haythornthwaite, 2002). Social interaction is key to collaboration (Kreijns, Kirschner, & Jochems, 2002). Thus, research on collaborative learning requires exploration of social interactions among learners. According to Vygotsky (1978), social interaction plays a fundamental role in the development of cognition. Within the framework of social constructivism, learning involves peer interaction, including discussion. In other words, learning occurs in a community setting which can be described and analyzed from a social network perspective, which tells us that a community is established through relation(s) linking community members to each other, for instance, reading others' notes in this study.

To study the development of learning communities (and its effect on learning), it is important to understand the nature of learning communities. According to Lock (2002), a community is not only a *product*, but also a dynamic process that evolves with time. As for the nature of learning community, Jonassen, Peck, and Wilson (1999) claimed that learning communities are characterized as a “common cause of mutual support and learning, by shared values and goals” (p. 118). Communication, collaboration, interaction, and participation are four cornerstones for a learning community framework (Lock, 2002). Communication is thought of as pivotal in an online community. Without effective communal communication there is no community (Schwier, 2001). In this sense, researchers with interest in the sustainability of learning communities can analyze the relations linking community members. In other words, the formation and development of a learning community is manifested through revealing the change of a relation or a set of relations that links learners to each other. In CSCL approaches like knowledge building (Bereiter, & Scardamalia, 1996, Bereiter, 2002), the relations among community members are normally established through a series of information and idea exchanges, such as reading and commenting other students’ notes.

Questions regarding the development of learning communities are essentially about the dynamics related to the formation and development of social networks in terms of their size and stability. According to Guastello (2002), communication entails information flows between actors, who are responsible for the development positive and negative feedback channels. This suggests that a non-linear dynamical process underlies the formation and development of learning communities. According to a principle of non-linear dynamical system theory (NDS, Guastello, 2002), the evolution of a non-linear dynamical system is at some stages slow and gradual; the slow and gradual effects culminate into sudden and discontinuous changes of events and conditions. This principle can be used to establish the dynamics of community formation and development, and the conditions under which the non-linear dynamical development of communities unfolds, which will be explored in this study. Dynamics is the study of how variables affect each other over time (van Geert, 1997). Philosophically, dynamic system theory is anti-reductionistic. According to dynamic system theory, the behavior of the system is not influenced in a simply linear way by the factors operating on within it, but is influenced in nonlinear and interdependent ways.

## **METHOD**

### **Participants and procedures**

The participants were students using online discussion in two educational settings. The first database was created by 28 grade four students (approximately ten years old) in a school in metropolitan Vancouver. The school was in an above-average area in terms of socioeconomic status, but the class had a typical range of students in terms of achievement. The students had not used online discussion before but had spent several months developing an offline learning community. The use of online discussion was integrated closely with other classroom activities as students studied electricity and First Nations issues in British Columbia. The students had access to the database from several computers in the classroom and visited a computer lab two to three times per week. The second database was created by 12 graduate students taking a one-semester course on knowledge building (van Aalst & Chan, 2001). In this case, the online discussion was used to discuss the course’s readings; developing an online community was especially important as the course consisted of two cohorts and the students did not all meet face-to-face. Each cohort met independently on a weekly basis, and the course was also supported by three videoconferences.

### **Data and Measures**

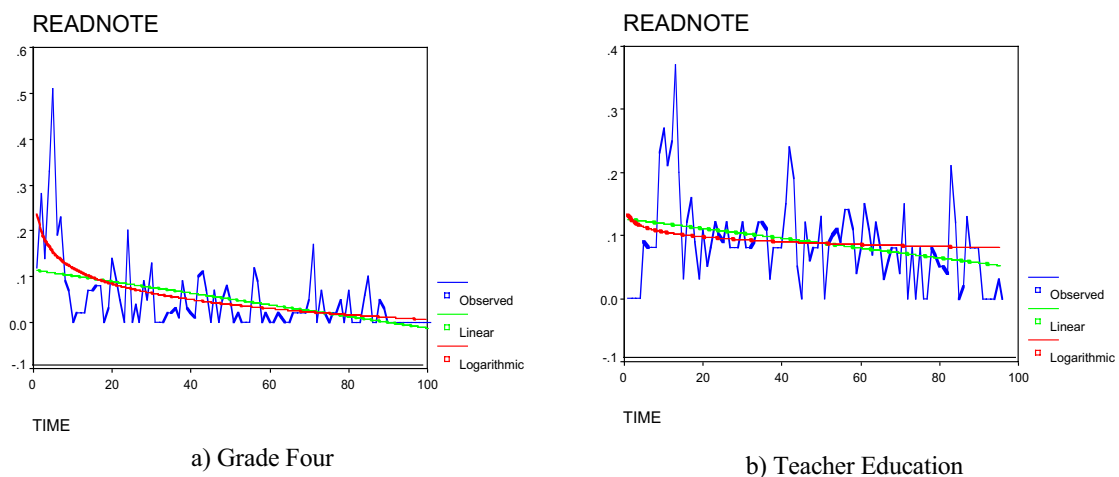
The two classes used a Knowledge Forum™ (KF) database to record how their collective ideas were developing. KF is a computer-based, communal database that students develop to collaboratively build understanding of certain problems (Bereiter & Scardamalia, 1996). Students’ collaborative contributions can manifest themselves in a variety of activities maintaining collections of notes that represent their understanding of a shared problem. The database can be used to track how individual students and the class as a whole improve understanding, and how understanding progresses. Students write notes; these notes can be read and responded to by others students who have access to the database. In this study we focus on the percentage of notes that have been read per participant. This variable was measured for each day that the databases were active. Note reading is necessary for acquiring information, exchanging ideas, and working to collaboratively improve ideas in CSCL settings. Percentage of notes that have been read per author can, in some sense, be conceived of as the extent to which the class can be expected to be familiar with ideas, information, and theories posted in the database. No online learning is possible with very low amounts of

reading each other's notes, as notes record the participants' ideas, information, comments, and so forth. In this sense, percentage of note read by per participant, to a certain degree, represents the extent to which the students engaged in knowledge building activities, although note reading was not the only learning activity in which the students engaged (e.g., they also responded to notes). However, note reading is a prerequisite for other actions.

This study aims to preliminarily model the organizational change and development of social networks occurring within a CSCL community from a NDS perspective (Guastello, 2002). Recent dynamical thinking about social networks involves the issues related their formation, development, and stability. In a general sense, the formation and development of networks can be characterized with the growth of the number of links in the network over time. In this study, the quantity of note reading obtained from a software retrieving server-log data from the KF server (the Analytic Toolkit for Knowledge Forum, ATK, see Burtis, 1998), will represent this link. A nonlinear regression model with Lyapunov exponent (Guastello, 2002) is introduced to test whether the targeted CSCL communities were undergoing a chaotic expansion positive Lyapunov exponent), were attraction toward a stable state (negative Lyapunov exponent), or were showing oscillating behavior.

## Results

All the data from the two example databases were analyzed through curve estimation in SPSS.11. The trajectories of the percentage of notes read in both databases are shown in the figure below.



For the grade four data, both linear and non-linear regression models (exponential function models) were calculated to fit the data. The non-linear model provided a better fit to the data than the linear model ( $R\text{-sq}=.37$ ,  $F=57.39$ ,  $p=.000$  compared with  $R\text{-sq}=.23$ ,  $F=29.79$ ,  $p=.000$ ). This means that the dynamics of note reading in this community had a fixed point attractor describing that note reading vanished exponentially. An attractor is a fundamental notion in complex system theory, and refers to states towards which a system may evolve when starting from certain initial conditions (Guastello, 2002). In a general sense, a fixed-point attractor makes a behavior gravitate toward a steady state or a constant value. Other types of attractor include magnetic attractor (fixed-point is a special case of it), chaotic attractor, and periodic or quasi-periodic attractor (Guastello, 2002).

There were three peaks in the teacher education data: near the start, at approximately 40 days, and at approximately after 70 days. From the start to the first peak the percentage of notes grew linearly ( $R\text{-sq} = .31$ ,  $F=8.2$ ,  $p=.012$ ); these data could not be fit to an exponential function ( $p=.10$ ). Between the first and third peaks there were short but quasi-regular oscillations, that is, a limit cycle similar to a sinusoidal wave. Between second and third peaks, there were chaotic oscillations. In this sense, the development of this teacher education database in terms of note reading is essentially is non-linear with a quasi-periodic attractor that is an attractor in non-linear dynamical system holding objects in a limit cycle around the attractor center (Guastello, 2002). The following pedagogical events can help us interpret the three peaks. Approximately 3-4 weeks after the beginning of the course, the class had established standards for participation. Six weeks later, the students wrote portfolio notes stimulating note reading, and they

stopped contributing regularly that naturally decreases the activities of reading notes (van Aalst & Chan, 2001).

According to the above brief analyses, it can be concluded that the two sample databases represent two different patterns of community development that should be described using different non-linear dynamical models (fixed-point attractor and quasi-periodic attractor). In any case, a linear model appears not to be sufficient to model the development of note reading in these communities.

## DISCUSSION

To date, there are few studies that examine the development of CSCL communities from a non-linear dynamical system perspective. To our knowledge, this study is one of the first attempts to investigate the development of CSCL communities this way. Although this was an exploratory study, it showed that nonlinear modeling described the evolution of reading in these databases better than linear modeling. One of us (the first author) will conduct studies to examine this issue in a large set of databases, and examine knowledge building design, teacher's pedagogical interventions, and student trait variables that may influence the different modes of development of online communities.

This study shows that the reading data are not merely irregular curves, but form a variety of non-linear trajectories. It is hoped that knowledge of critical points and the specific models that describe the data can be used to provide an empirical basis for instructional strategies that can support knowledge building. The non-linear trajectories should not be conceived of sheer irregular curves, but something embracing rich information related to teaching and learning. However, to do that, our analyses must be extended and include more dependent variables (e.g., linkages between notes) and independent variables (e.g., instructional design, the teacher's interventions, and motivation). This study has established a platform on which we will introduce the aforementioned variables and student individual variables to develop more comprehensive accounts of development of effective CSCL communities, linking emergent collective properties of the community to not only its components and their interactions (e.g. students' individual variables), but also to external constraints (e.g. teacher's intervention). The non-linear dynamical feature of the two targeted CSCL communities is emergent; and this means that it cannot be predicted on the onset of collaborative learning. That is to say, philosophically, determinism in principle, but unpredictability in practice underlies the NDS (Carver & Scheier, 1998). It only exists and arises from the interplay of internal factors and external factors. This is a manifestation of micro-to-macro emergence from individual actions (Sawyer, 2001). This goal will be achieved by measuring a substantial number of CSCL communities from which some basic types of non-linear dynamical development would be identified. The revelation of the dynamics of formation and development of CSCL communities will be informative of both CSCL designers and CSCL educators in terms of creating and sustaining CSCL communities.

## ACKNOWLEDGMENTS

This research was supported by a grant to the second author from the Social Sciences and Humanities Research Council of Canada. We also thank Michael Cummings (British Columbia School District 43) and Carol Chan (The University of Hong Kong) for supplying the data we analyzed.

## REFERENCES

- Bereiter, C., & Scardamalia, M. (1996) Rethinking learning. In D.R. Olson, & N.Torrance (Eds.), *The handbook of education and human development: New models of learning, teaching and schooling* (pp. 485-513). Cambridge, MA: Basil Blackwell.
- Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Brown, A.L., & Campione, J.C. (1990). Communities of learning and thinking, or a context by any other name. In D. Kuhn (Ed.), *Developmental perspectives on teaching and learning thinking skills* (Vol. 21). *Contributions to human development* (pp. 108-126). New York, NY: Oxford University Press.
- Burtis, J. (1998) *The analytic toolkit*. The Ontario Institute for Studies in Education, The University of Toronto: Knowledge Building Research Team.
- Carver, C. S. & Scheier, M. F. (1998). *On the self-regulation of behavior*. Cambridge University Press.
- Guastello, S. J. (2002). *Managing emergent phenomena: nonlinear dynamics in work organization*. LEA, Publishers Mahwah, NJ.

- Haythornthwaite, C. (2002). Building social networks via computer networks: Creating and sustaining distributed learning communities. In K.A. Renninger & W. Shumar, *Building Virtual Communities: Learning and Change in Cyberspace* (pp.159-190). Cambridge: Cambridge University Press.
- Hewitt, J. (2003). How habitual online practices affect the development of asynchronous discussion threads. *Journal of Educational Computing Research*, 28(1), 31-45.
- Kreijns, K., Kirschner, P. A., & Jochems, W. (2002). The Sociability of Computer-Supported Collaborative Learning Environments. *Educational Technology & Society* 5(1), 8-22.
- Jonassen, D. H., Peck, K. L., & Wilson, B. G. (1999). *Learning with technology: a constructivist perspective*. Upper Saddle River, N.J.: Merrill.
- Lock, J. V. (2002). Laying the groundwork for the development of learning communities within online courses. *The Quarterly Review of Distance Education*, 3, 395-408.
- Morrison, K. (2002). *School leadership and complexity theory*. New York, NY: Routledge Falmer.
- Sawyer, R. K. (2001). Emergence in sociology: contemporary philosophy of mind and some implications for sociological theory. *American Journal of Sociology*, 107, 551-581.
- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (ed.), *Liberal education in a knowledge society* (pp. 67-98). Chicago: Open Court.
- Schwier, R. A. (2001). Catalysts, Emphases, and Elements of Virtual Learning Communities: Implications for Research and Practice. *Quarterly Review of Distance Education*, 2(1), 5-18.
- Stahl, G. (2000). A model of collaborative knowledge-building. In B. Fishman & O'Connor-Divelbiss (Eds.), *Fourth International Conference of the Learning Science* (pp. 70-77). Mahwah, NJ: Lawrence Erlbaum Associates.
- van Aalst, J., & Chan, C.K.K. (2001, March) Beyond "sitting next to each other": A design experiment on knowledge building in teacher education. In P. Dillenbourg, A. Eurelings, and K. Hakkarainen (Eds.), *European perspectives on computer-supported collaborative learning: Proceedings of the First European Conference on Computer-Supported Collaborative Learning, Maastricht, March 22-24, 2001* (pp. 20-28). Maastricht, the Netherlands: University of Maastricht.
- Van Geert, P. (1997). Determinism and nonlinear dynamic model building in development. In A. Fogel, M. C.D. Lyra & J. Valsiner (Eds.). *Dynamics and indeterminism in development and social process* (pp. 13-38). Lawrence Erlbaum Association, Publishers, Mahwah, NJ.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Woodruff, E. (1999). Concerning the cohesive nature of CSCL communities. In C. Hoadley (Ed.), *Proceedings of Computer support for collaborative learning. Designing new media for a new millennium: Collaborative technology for learning, education, and training* (pp. 677-680). Palo Alto, CA: Stanford University.