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ABSTRACT

Social semiotics suggests that social and cultural formations, including the language and practice of science and the ways in which new generations and communities advance them, develop as an integral part of the evolution of social ecosystems. Some recent models of complex dynamic systems in physics, chemistry, and biology focus more on the process of a system (individual development, species evolution, ecological succession) than on the product. Ecological succession can be seen as an alternative to development as a basis for models of social learning in science. While a developmental model assumes that development occurs the same way each time, ignoring individuation, a successional model looks at how complexes of interdependent species (whole animal and plant communities) develop over time in interaction with each other and with the physical environment. Successional models have a mosaic character, with subgroups in the ecosystem following the same processes at somewhat different rates. A new idea entering this ecosystem may flourish or not, depending on the conditions and processes within the ecosystem, and may change the environment for future ideas. While traditional models of science education emphasize mastery of a curriculum, the successional model promotes true intellectual development as a dynamic, evolutionary process. Contains 46 references. (MSE)

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SCIENCE, SEMANTICS, AND SOCIAL CHANGE

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Science and Social Semiotics

What are 'scientific concepts' and 'scientific reasoning' if we regard them as linguistic and social processes? How do they differ from the processes most students and most people ordinarily use? What are their social functions? How do they arise and change historically? And to what extent should we expect their development in an individual to recapitulate their historical emergence and evolution?

These are questions that define a particular theoretical perspective on education, one that begins from a view of social systems as systems of human cultural practices which are simultaneously material and semiotic. The various things that different people in a society do are tied together in a complex web of relationships. From one point of view each human action has a social and cultural meaning, and relationships among actions depend on these meanings. This is the semiotic perspective. But at the same time, every cultural act also engages some material process, and therefore there are also material relations among them: relations of exchange of matter, energy, and information (entropies). Human social systems, regarded as systems of actions, as systems of socially and culturally meaningful practices, help to constitute and modify functioning material ecosystems. This is the ecosocial perspective. Social semiotics, as a theory of ecosocial dynamics, strives to unify these complementary perspectives.

While the elements of social semiotic theory are familiar, its particular ways of organizing these elements into a useful theory may not be. Social semiotics is a synthesis that has grown out of the social linguistics of Mikhail Bakhtin (1929, 1935, 1953) and Michael Halliday (1976, 1978, 1985), the social communication theory of Gregory Bateson (1972), and the social discourse theory of Michel Foucault (1969). It sees social systems and cultures as composed not of people as such, but of the different kinds of things people do, and the relationships that tie their social practices into a true system. Social practices are looked at, apart from the material processes they engage, as essentially processes of making meaning. Everything we do: speaking, gesturing, drawing, dressing, calculating, cooking, and even killing acquires social meaning within a complex system of semiotic relations of equivalences and contrasts, similarities and distinctions, categories and elements, wholes and parts, types and tokens, positive and negative valuations.

The paradigm example of this is speech, the use of language for social purposes, deploying the semantic resources of *a language* (i.e. its various specialized registers) in recognizable, socially meaningful patterns (genres and other discourse formations). Social linguistics asks *what* people do with language and *how*. It looks beyond the sentence to the semantics of text and discourse, and beyond the text to meanings made through the relationships among different texts (intertextuality). It looks beyond the speaker's utterance to dialogic relations with actual and even possible interlocutors (social dialogism). It looks beyond the individual to the ways of speaking of various social groups and categories within a culture, a society, a community. It looks at relationships of agreement and conflict among groups and their discourses, and how these are socially constructed in part through discourse (social heteroglossia). And it looks beyond present uses of language to their historical origins, changing social functions, and possible futures for the group, the individual, and the social system as a whole.

Social semiotics does not recognize the artificial demarcation of speech from other forms of social action. There are relationships of meaning, semiotic relations, among all possible meaningful acts in a community: all actions can be assigned places in semiotic systems. Action has its grammars, its genres, its 'intertextuality' and its 'heteroglossia'. Social semiotics sees the great web of doing as tying a social system together, culturally and semiotically, but also materially. Because of its unitary view of semiotic practices and material processes, social semiotics also requires all social systems to be dynamic: developing, changing, evolving at all level and scales. It is obviously not possible to summarize such a theory adequately in this brief paper. In addition to the references already given, more comprehensive introductions and bibliographies are available in Halliday (1978), Lemke (1984, 1985, 1987, 1988a, 1989a, 1990a, in press), and Hodge & Kress (1988).

Our particular interest here is social semiotics' implications for educational questions, particularly for the case of science education, though everything social semiotics has to say about education in science has its analogue for educational issues in other disciplines as well. Social semiotics does not talk about science, or any other domain of human action, apart from an analysis of how it meanings are *made*, in and through language and other semiotic resources for action, nor apart from consideration of the social functions of scientific practices, both overt and covert. Social semiotics regards the doings and the discourses of science as culturally, socially, and historically specific human practices constructing edifices of meaning and material linkages within a social ecosystem.

What then are 'scientific concepts' and 'scientific reasoning' when regarded as linguistic and social practices? They are, first and foremost, ways of making meaning. They are features of scientific discourse, of a way of talking and its associated doings. We do science in large part in and through the medium of language. Observing, describing, comparing, classifying, analyzing, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing, lecturing, and teaching science are all scientific practices that are accomplished by the deployment of scientific discourse. In analyzing scientific practices, social semiotics takes from social and functional linguistics a very rich and sophisticated theory of linguistic discourse and weds it to a general semiotic theory of action.

A scientific concept, for example, is clearly not the same as a scientific term, though we use terms as the names of concepts. But neither is a concept some mysterious mental entity prior to or outside language and discourse (cf. Lemke 1989a, 1990a). It corresponds essentially to a *semantic item*, the more abstract linguistic element for which a particular word or phrase, a *lexical item*, may serve as realization or instance in a particular text. In a more functionalist theory of semantics (Lemke 1983, 1990a) we can more precisely identify it with a *thematic item*, which is specific to a particular network of interrelated concepts, all of which are used and defined in terms of one another in a particular specialized field of discourse.

Particular lexical (or phrasal) items, such as *light, light energy, sunlight, solar energy* may all represent the same thematic item in the scientific discourse of a particular topic, or they may not. Their potential semantic differences may be made use of for purposes of contrast, or neutralized for purposes of generality. While formal written scientific texts often try to maintain a principle of one lexical item for each thematic item, the language of classroom science, of spoken scientific discussion, and of many textbooks and less formal scientific writing finds it communicatively and pedagogically useful to deviate from this very restrictive specialized convention. It is particularly important in the teaching of science to identify when the <u>same</u> lexical item, as used by students, does and does not correspond to the same thematic item (concept) used by the teacher or the textbook. Do the students' words mean what we would mean if we used those same words in that same way? This is essentially a problem in text semantic analysis (see for example Lemke 1990a, Chap. 2). What matters for its solution is not an analysis of interior intentions or cognitive processes, but a straightforward analysis of how teacher and students are using language.

To have mastered a concept is to make use of it. But discourse analysis shows that concepts are not used in isolation, but always in networks or clusters of semantically (actually, thematically) related concepts. To use such a *thematic formation* is to speak an identifiable kind of discourse while talking one's way through a problem, describing a specimen or process, formulating a hypothesis, or making a generalization. The notion of a 'scientific concept' is a naive, 'pre-scientific' notion. Thematic formations are what the 'content' of science is all about. They are not cognitive or mentalistic; they are linguistic, semiotic, discursive, social, and cultural formations, even if they may also occasionally be idiosyncratic ones. They can be described in great detail in terms of their semantic features and relations in ways that allow the abstract formations to be directly identified in a word-by-word analysis of spoken or written classroom or scientific discourse (e.g. Lemke 1983, 1990a).

A similar analysis can be made of 'scientific reasoning'. Reasoning, at least actual instances of it, is primarily a verbal process (supplemented certainly by other symbol-manipulating semiotic processes such as calculating and diagramming). What makes an argument 'logical' is that its verbal form can be fit to a certain set of patterns (such as the classical syllogisms and enthymemes) that associate grammatical elements of what is said with their logical force or function in the argument. The privileged patterns which a particular community endorses as 'logical' (or 'coherent' or 'well-spoken') define arrangements of semantic relations among the functions (e.g. relations of sequence, implication, exemplification, induction, narrative, etc.). Regarding the functions as speech-acts, i.e. as actions performed by speaking, the paradigms of logical or scientific argument constitute a type of discourse formation most commonly known as a *genre*. Genres are the organizational templates for speech-action. There is an extensive literature on the nature of (we are speaking mainly here of non-literary) genres, and on their importance in education (e.g. Propp 1928, Bakhtin 1953, Hasan 1989, Martin 1989; Lemke 1988b, 1989a, 1990a).

One can get a sense of what is meant by a genre simply by transferring our intuitions about action to speech and language. There is an action genre of Washing-the-Dishes or Getting-the-Check in a restaurant, as there is of nearly every complex human performance. There are certain functions to be accomplished, usually in a particular order, with some optional and some obligatory, each with a specific functional relation to the others, and altogether such that one recognizes them as forming a whole. Speech genres and written genres are much the same. Think of the linguistic genre of a Formal Definition as the action genre of actually writing one out: you have to name the thing-to-be-defined (the *definiens*), identify it as a member of a general category (the *genus*), and furthermore as the member of that category with a particular set of distinctive properties (the *differentia*). 'A Square is a Rectangle with four equal sides.'

A syllogism is more complicated than a definition, but still an easily describable genre. More complex forms of argument can also be analyzed as genres, and canons set up to judge the arguments culturally as 'logical' or not, and beyond that as corresponding to the various norms and preferences of 'scientific' discourse. It is possible to say as precisely as the community's actual practices allow in what ways a particular text is or is not 'logical' and 'scientific' using the machinery of text semantics (Lemke 1983, 1985, 1988a, 1988c, 1990a, 1990b).

'Scientific reasoning' or any of the more specific processes of comparison, classification, induction, deduction, generalization, exemplification, etc. is essentially a deployment of one or more semantically linked thematic ('science content knowledge' 'concept clusters') formations in the organizing functional framework of a particular, scientifically approved spoken or written genre. Both thematic and genre patterns are social, cultural formations: they are ways of deploying the semantic resources of language (and other semiotic resource systems) that are regular, repeated, and recognizably identifiable in a particular community. A language sociologist might say that they are sedimented institutions of language use.

Social semiotics reminds us that they are also dynamic phenomena, constantly changing, and that they exist in many, often competing and conflicting variants that form the reservoir of diversity on which longterm social change depends.

Science and Colloquial Language

How different is scientific language from the language that most people, including most students, ordinarily use? To the extent that mastery of science is the mastery of its specialized modes of discourse, its thematics and its genres (including the actional genres that link scientific discourse to other forms of action like pointing telescopes and connecting circuit elements), bridging this difference is the essential task of science education.

Science and colloquial language differ in many ways, all of which create obstacles to teaching and learning science. Linguistically, the language of science is a *technical register*, that is, a system of weighted probabilities which indicates which of the semantic resources of the grammar and lexicon of the language will be most or least frequently deployed in texts of this register. Registers are defined by specifying, to varying degrees of precision, the particular topics, tasks, social functions, and media in which the language is being deployed. The register of science, as such, averages over all the variations within and among the different specializations and tasks, thematics and genres of all scientific language, spoken and written, in all situations.

It is more useful to begin by distinguishing between the spoken and written registers of science, and between those of professional science (e.g. lab talk, journal reports) and those of school science (textbooks, classroom discourse; Lemke 1989b). Their relations are complex, but in essence all are dominated by the conventions of formal, written scientific discourse, which is also the language variety most different from the ordinary colloquial language of students.

These differences are trivialized if we think of them solely in terms of specialized technical vocabulary. The differences are much more profound and difficult to bridge. We have already seen that technical vocabulary merely provides the wording for new, specialized systems of conceptual relationships, the thematic formations of scientific discourse on any particular topic. Students cannot simply memorize definitions or learn new vocabulary by glossing. They need to learn how to use new terms in context: in the context of the topic, in the context of a task or problem, and most especially in the context of other, related technical terms. Talking `Science' means using two or more technical terms in the same clause or phrase, or at least in two logically articulated clauses of the same sentence. `Using the word in a sentence' is less than halfway to the goal unless that sentence already contains other technical terms (or at least non-technical synonyms standing in for the technical thematic item).

But learning the semantic relationships among technical terms (i.e. learning to use a whole thematic pattern in discourse) is still only the beginning. Scientific registers, because they are dominated by the conventions of written English, are alien to students in other ways than just thematically. Written English in our period of history has an exaggerated preference for certain grammatical forms that is carried to its extreme in scientific writing (though burocratic style is not far behind, being almost a caricature of technical language).

Written Scientific English eschews verbs of material action, and often those of mental process as well, in favor of verbs of abstract relation (e.g. *is, has, becomes, represents, involves, requires, relates, corresponds*, etc.) and, sometimes metaphorically, verbs of verbal process (*say, assume, describe, identify, express*, etc.). The thematic content is then carried by words which are grammatically nouns or nominals, but semantically are still processes (e.g *condensation, excretion, radiation, oscillation*, etc.). The all-important semantic relations among terms are expressed in very condensed ways within noun phrases (`radiative oscillation' `thermal expansion') and then in very abstract (and often vague or ambiguous) ways through the relational verbs and occasional clause-linking conjunctions. In many cases, unless you already know the thematic pattern from another text, you could never reconstruct it on the basis of what is actually written. In this way technical language builds on itself, compressing paragraphs into phrases in order to link them to other, equally condensed phrases. For a more complete discussion see (Lemke 1990b; Halliday 1988, 1989; Wignell, Martin, & Eggins 1989).

All this is very unlike nearly all spoken language, and certainly unlike the colloquial registers students are most comfortable with. It is also unlike most literary writing (except some essays) and is not dealt with in the literature-dominated Language Arts curriculum. Estimates of the `readability' of science text which do not take such matters as thematic compression and relational-verb grammar into account are useless. You can immediately improve the readability of scientific text by expanding its compressions (thereby increasing the number of clauses and so of finite verbs), replacing the relational verbs by explicit conjunctions linking clauses, and de-nominalizing the processes, greatly increasing the proportion of material action verbs. It also helps to gloss technical terms parenthetically.

None of this however addresses the problem of genre differences. The way in which scientific discourse describes, compares, argues, informs, generalizes, and generally 'reasons' is highly specialized. It is not like literary description and comparison or even like argument and generalization in history or mathematics (which is closest to it). Students who do not learn how to write science will generally have only an incomplete sense of how to read it. If you do not know how to put together a Formal Definition, you are likely when reading one to miss such essential implications as that there are other kinds of rectangles than squares, or even that a square is a rectangle. Not only are all these thematic implications never spelled out explicitly in written science (though often relied on to fill in missing bits of later arguments), but even in the most helpful classroom spoken discourse of science, most remain implicit.

Beyond all this there are cultural and social differences. Written Science is a specialized register of Standardized Written English (SWE), which is in turn based on a single, rather rare dialect: Upper Middle Class Spoken English (UMCE). Not just in pronunciation and orthography, not just in grammar and lexis, but in discourse structure and rhetorical organization, SWE and UMCE differ significantly from the other social class, local, and world dialects of English. Very few people in America speak what we are naively taught to call 'good English', i.e. UMCE, especially in urban centers where sociolects, creoles, hybrids, and nativized Englishes abound (e.g. Afro-American English, the Caribbean and Hispano-American Englishes, Chinese-American English, Working Class sociolects, etc.). It has probably never been true that more than a small fraction of the U.S. population spoke UMCE or anything that could approximately pass for it.

Again, these differences are not merely superficial ones, but basic semantic and discourse structural ones. They affect conceptual understanding. Recent pionerering work on the differing semantic orientations between working class and upper-middle class mothers and children in Australia (Hasan 1986, Hasan & Cloran 1990) is now being extended to school discourse. The earlier, widely misinterpreted work by Bernstein (1973, 1987) in England, and the classic study by Heath in the U.S. (1983) have prepared us long ago for these difficult conclusions. Sociolectal differences in discourse strategies clearly do not correspond to the prejudices of those who believe their own linguistic variety superior, but they do enable mainstream education to invisibly discriminate against all students who have not inherited the privileged UMCE dialect.

The same conclusions apply to speakers of Afro-American English and all the other richly diverse dialects that comprise American English, including non-native speakers whose 'accents' and 'mistakes' in English are often simply the hallmarks of a distinct community dialect. All these students are as ruthlessly discriminated against today because of their linguistic differences as they ever were because of their racial or cultural differences. The tyranny of UMCE and SWE in the curriculum demands of students not simply a difficult and alienating shift of sound and grammar, but a profound and unnecessary re-organization of their basic strategies for making sense of the world. It asks them to speak, write, and see life as if they led the upper-middle class lives most of them never will. It rejects diversity and refuses the changes in scientific, literary, historical, artistic, and political discourse that admitting that diversity on the equal basis it deserves would bring. It fosters grossly unscientific myths about the necessity and value of 'Standard English' (and the relegation of other varieties) that will someday seem as absurd as the similar doctrines of racial inferiority and gender stereotyping that were still widely accepted in this country not so very long ago (Lemke 1990c, 1990d).

From Social Dynamics to Educational Theory

Social semiotics provides more than simply an analysis of what education in science aims to teach and how far those discourse practices are from where most students begin. It can suggest many specific instructional strategies to help students learn to use the discourse of science, and these have been more fully discussed elsewhere (Lemke 1990a, esp. Chapter 7). It can also indicate, as I have just done, that we make the task unnecessarily difficult for ourselves and for our students by uncritically accepting language discrimination in our schools. But social semiotics ultimately has an even more ambitious agenda and is beginning to suggest still other kinds of changes in teaching that apply both to science and to many other fields.

Scientific discourse is not a static phenomenon. It is constantly changing, at every level from lexicon and thematics (which can change relatively rapidly), to genres and rhetorical strategies (changing more slowly), to grammatical preferences and semantic orientations (changing only very slowly on the scale of human lifetimes). Scientific discourse changes as an integral part of the total social activity of doing science and all the other actions in which scientific and technical discourse plays a part. An adequate theory of discourse change cannot be separated from a general theory of social change, and social semiotics is now stretching toward this still distant prize (Lemke, in press). But already there are some intriguing ideas that seem to have important educational implications.

A social ecosystem is about as complex a dynamical system as one could hope to model. Its myriad processes and activities, natural and technological, are strongly interconnected and interdependent, resulting in highly non-linear behavior of the system as a whole. Such behavior lies largely outside the intuitions of traditional scientific analysis, whose linear methods work well only for very simple isolated systems and linearly designed machine technologies. The largely non-linear study of complex systems, however, is now well advanced in physics and chemistry (e.g. Prigogine 1980, Prigogine & Stengers 1984, Jackson 1989, Harrison 1982) and is beginning to make progress in developmental and evolutionary biology, ecology, and geophysiology (see Weber, Depew, & Smith 1988; Odum 1983; Salthe 1985, 1989; Holling 1986; Lovelock 1989). In the framework of social semiotics this work of the last decade or so has much to say to the social sciences and to education (Lemke, in press).

In particular, social semiotics suggests that social and cultural formations, including the language and practice of science, and the ways in which new generations and communities learn and in their turn advance that language and practice, develop and evolve as an integral part of the material evolution and development of social ecosystems that can be described by physical and biological theory, supplemented by semiotic description of the social meaning relations that inform the linkages and interconnections of the material processes of human activity. I want to describe just one small part of such a model insofar as it may apply to education.

Developmental models are hardly new in education, but their justification has traditionally been a psychological, and more recently and particularly a cognitivist one. These older theories appeal to a traditional ideology of individualism and to the understandable popularity of mentalism with intellectuals. They misdefine the system of relevance, mistake the nature of the data they use, and rely on inadequate conceptual models already long outmoded in biology. The system of relevance in intellectual maturation is not an isolated individual developing under an internal genetically governed program, but a community ecosystem of social practices in which the individual, usually as part of a group, actively participates in the creation of a unique variant of a system of practices broadly shared by other groups of similar type. The data on which cognitivist models are based are never neurological or mental, but always linguistic or semiotic and behavioral. More particularly they are specific deployments of shared social resources for meaning: grammars, semantics, genres, discourse formations, and actional formations which characterize communities, not `minds'. Development is not a relatively automatic process of fixed stages governed by an internal program, but an active exploration of a landscape of partly self-made possibilities conditioned by environmental influences (including the internal environment of genome-guided chemistry) and resulting in a developmental trajectory that partly recapitulates the past turnings of like systems and partly creates new and unique dynamic states that may or may not in turn be recapitulated by other systems in the future.

The steady pressure of linguistic and social models of development and learning is already pushing the cognitivist paradigm to a social-cognitivist synthesis. Local intellectual evolution may owe something retrospectively to cognitivist discourse as a stage on the way from naive behaviorism to a semiotically informed and socially sophisticated theory, but `mind' and its associated notions are as unlikely to have a scientific future as `soul' and the other, older forms of mentalism from which they derive historically. If we want a true neuro-linguistics and eventually a general neuro-semiotics, we will just have to wait until neuroscience and social linguistics and semiotics are mature enough to have something real to offer each other. No mentalist middlemen are likely to be needed, nor will their biasing of the research enterprise away from politically dangerous inquiry into social processes and community conflicts and towards the safety and sterility of imaginary internal mental activity be missed. (For more detailed social semiotic critiques of mentalism, see Thibault 1986, Lemke 1989, Threadgold 1989).

The more recent ways of modeling complex dynamical systems in physics, chemistry and biology with which social semiotics is engaging suggest not just a different sort of developmental model, but a redrawing of intellectual boundaries between such apparently different phenomena as individual development, species evolution, and ecological succession. In particular, development and succession can be regarded as two different variations on the same process, one in which the dynamical complexity of a system matures in a partly predictable way. What evolves, in this view, is not a species of individual per se, but rather the developmental or successional trajectory of a type of system: how it develops, rather than simply what it becomes; all its stages (larva, pupa, butterfly; embryo, juvenile, adult, senile, perhaps even corpse), not just one arbitrarily designated stage. This is a truly dynamical notion of an entity extending across time (in fact *making* its own local, proper time) which cannot be reduced to any single moment on its life-trajectory. Add to this the complementary notion that the trajectory has the shape it does largely because of interactions with the environment, present and in the evolutionary past of its type, and that the dynamics of the individual or sub-system can only be analyzed as part of that of the encompassing, integrating supersystem (say the social ecosystem), and one has the beginnings of a radically different view of individual development and of learning (for an early discussion of some of these points, see Lemke 1984, pp. 25-58; more recent discussion in Lemke, in press, and references therein).

The traditional paradigm of embryological development, relatively autonomous and internalist, does not fit well with the needs of educational, or social theory. It also does not extend well from the classical notion of an 'individual' organism to notions of the development of groups, communities, or ecosystems. This is why the paradigm itself has been undergoing change and generalization. While it would be difficult in a short paper to provide the necessary background to apply the new, more general models themselves, it is still possible to suggest some of their scope by looking at ecological succession as an alternative basis for models of social learning in science and other subjects.

Ecological Succession and Social Learning Theory

The weakness of developmental models is that they were fashioned to describe *relatively* autonomous development, such as embryogenesis. They focus on a single individual and treat the environment as a black box from which the system extracts (actively, at best) needed nutrients or information. They assume that development, so far as it is of interest, proceeds in the same way each time. They ignore individuation of development (unique aspects), evolution of developmental trajectories, and interdependence (current and historical co-evolution of trajectories) of system and environment. Successional models for ecosystem development, on the other hand, look at how complexes of interdependent species, whole animal and plant communities, develop over time in (two-way) interaction with one another and with the geophysical environment (local geology, soil conditions, climate, land- or sea-scape, ocean currents). They must take into account co-evolution of species, and they are quite concerned with the uniqueness as well as the typicality of the historical successions of particular ecosystems.

One of the salient features of successional models is their 'patchy' or 'mosaic' character. Large ecosystems consist of local patches which may be of different ages, have different micro-conditions (soil, microclimate, micro-geology), and follow somewhat different successional trajectories, while still being in close interaction with one another. A small fire in a forest, or even the fall of an old redwood, clears a new patch which will begin to follow a successional trajectory in which the particular species and their relative numbers, the forms of their interaction with one another, their total cumulative cycling of water and nutrients, their total biomass and energy and entropy production, and other ecosystem indices gradually change. In marine systems, upwelling zones and currents, or just the bottom geology or river inflow locations in lakes, also produce patchiness. Each patch is a small, less than autonomous ecological subsystem. A young patch surrounded by older forest will follow a different trajectory than one not surrounded. A mature forest will have younger and older patches side by side.

The net effect of a young patch's being part of a larger, more mature ecosystem is that it's successional history will tend to converge toward the state, or the trajectory, of the dominant system. The seeds and other propagules that first land on the newly burnt-out patch may come from mature trees in surrounding patches. Some of these may flourish, but others may require precursors: intermediate species that modify the soil or light conditions in a way that favors them. Real successional histories, as opposed to the idealized ones in textbooks, are a mixture of the sequential-stage ecologies leading to a 'climax forest' and various local 'short-cuts' based on the fact that later-stage systems already exist nearby. Different patches will pursue partly unique trajectories while still tending to a common equifinal balance with surrounding communities. It even happens that within one patch, or between neighbors, there are conflicts in the basic conditions for a constant or steady-state dynamic equilibrium ever to be reached, with the result that there is a disequilibrium steady-state: several different, incompatible configurations of species (trees, brush, insects, birds) alternate in a regular or erratic (chaotic) fashion (cf. Holling 1986). In this way the total system maintains a higher level of diversity (over time) than any equilibrium state could accomodate, and may even provide the system with greater resilience to changes in overall conditions (climate, mutated species, human activity).

In the general theory of complex dynamical systems, succession and traditional individual development are just two special cases of the same general developmental process. But successional models add many conceptual resources for our understanding of social learning in such a newly generalized developmental perspective. In human communities we also find `patches' of social activity in which a new generation or a new community, arising from age-difference, special local conditions, or catastrophes that have set them back, if not to the Stone Age, at least to a less complex and interconnected state (by quite specific ecological and thermodynamic criteria). These patches of humanity, and their associated ecosystems, will forge new trajectories, partly unique, and partly convergent with those around them (cf. industrial development in post-war Japan). Individual human organisms in these patch communities will participate in these processes and some of the changes they undergo we have traditionally called `learning'.

The patchiness of ecosystems exists on many scales, from large sections of forest to small patches measuring a meter across, or even less. Smaller units are integrated ecologically into larger ones. Human community patchiness also has its scales, down, for present purposes, to the individual organism, whose developmental trajectory as a member of a social group is an integral part of the successional history of the group and the larger communities of which it is in turn a part. Learning is an essentially social process: it takes place in communities, through social interaction. What is transmitted are social systems of practices and their meanings (languages, genres, discourses, activity norms and procedures) that are characteristic of social communities. But both the traditional model of the autonomous learner and that of teaching and learning as transmitting and receiving are hopelessly inadequate scientifically and even seriously misleading as metaphors.

Imagine students in the classroom or children on the playground as a small patch in the human social ecosystem. They are a relatively `immature' patch, enacting a new successional trajectory partly unique to their group, and partly convergent with those of many other like groups in the same larger community. They will share a dialect of some language with the larger community, but their own patterns of language use will remain to some degree local and idiosyncratic to the patch. They will develop their own ways of reading and writing, of talking science and other subjects, under the influence of the more mature systems around them, through active interaction with teachers, books, parents, television, and slightly older individuals. Some of what they do which is unique may eventually be copied and become the norm for a larger community of the future (cultural evolution).

We can improve this model still further by shifting focus from individual organisms to the actual processes that constitute their mini-ecosystem. Ecosystems consist of organisms in only a rather naive sense: the relationships that define an ecosystem are not relationships between organisms as such, but between the various things that these organisms do. Ecosystems are systems of relations among processes, not systems of organisms. Social systems, communities, likewise are not systems of individuals, but systems of organizing relations among the doing of individuals, among what I have been calling social (or cultural, including linguistic) practices. It is these practices that develop and evolve, or more precisely, it is the developmental trajectory of a system of interrelated practices which evolves, and the system of material processes underlying the socially meaningful practices which develops (Lemke, in press).

Our ecosystem patch now should not be thought of as a group of individuals, but as what those individuals are doing. In particular, what those individuals are doing that is systematic and repeatable (allowing for normal variation): their habits of speaking and acting; how they write, how they talk about atoms, how they play baseball; their eating habits, dressing habits, fighting habits. All these typical practices of the group, or of an individual, are deployments of the resources of a cultural system. The particular doings of a particular patch (on some scale) are always a little unique, and always changing a little. They are enacting their particular successional trajectory.

Onto a patch falls a seed. This 'propagule' is a <u>doing</u>, a social practice, perhaps a way of talking about atoms, perhaps a way of holding a baseball bat. It comes from the surrounding, more mature community. What role will it play in the successional trajectory of the patch? Will it be noticed? Will it be recognized as new? Will it be imitated? How closely? Will it be deployed in similar contexts in the new patch as in the community of origin? Will it change conditions in the patch so that another propagule can flourish there which otherwise would not have? Will it change conditions in the patch in such a way that the patch will innovate a practice that did not exist in the older community and which may eventually flourish there, perhaps replacing another practice? Will it perhaps even invade the parent community and change its practices, or those of other younger and future patches?

On what do the answers to such questions depend? Clearly not just on the state of any one individual organism at just one time. The ecological model has much to recommend it in analyzing social learning not just as a process by which the individual learns from the social environment, but as a unique process of individual and group change that contributes to social change and cultural evolution.

From an ecosocial perspective, 'learning' is one of the principal opportunities for cultural innovation and the initiation of social change. But the covert political function of most formal education is to suppress these potentially dangerous deviations. We do not encourage students to find their own ways of speaking, writing, or doing. We define their distinctive discourses about scientific topics as 'misconceptions' not as alternative theories. We try to insure that our seeds land first, that alien seeds are kept out, and that successional trajectories of new patches follow exactly the same path as did our own (cf. the conservatism of curricula). We do not treat variation and diversity as a potential resource of the system, as the original source of innovation, as the great reservoir of plasticity available to help survive calamity, as the variety within which will be found new means to solutions for problems the old means fail to solve. Educators are taught to disapprove even the least variations of dialect or usage, much less the inherent patchy diversity of genres, discourse structures, beliefs, theories, attitudes, values, and interests. Genuine diversity is never embraced by curriculum, and only rarely encouraged by even the most progressive methodology.

Exploring Some New Implications

Let's consider two specific implications of successional models for education in science and other subjects. In ecological succession it is often noted that a principle of 'survival of the first-est' applies. It is not necessarily the species that under some arbitrary conditions is 'best adapted' which comes to fill a niche or dominate an ecology: it is often simply the one that historically happened to get there first. Once entrenched, it may even alter the rest of the ecosystem to make it less hospitable to potential rivals. In learning, the first theory to be introduced often has an insurmountable advantage over other competing, perhaps even better theories. We may speak of emotional attachments, and ego-investment, but in terms of the system of social practices of an individual or group (and beliefs <u>are</u> the social practices of professing and acting on what mentalists call 'beliefs'), a belief-practice cannot be isolated, it is always integrated in countless (not always explicitly articulated or noticed) ways with other practices. Once entrenched, it is, if you like, <u>part</u> of the 'ego', not just of an individual, but often of a group (family, friends, peers, classmates, profession). It is not a mere 'misconception' to be rooted out, it is part of what makes someone who they are. The same is even more deeply true of the language dialects against which we still so shamelessly discriminate.

A few years ago I taught a learning theory course which was, according to the curriculum, supposed to cover several different theories. From semester to semester I varied the order in which the theories were taught. The first theory studied was always the one the students were most at home with during the rest of the course, the one that influenced their casual vocabulary and arguments when discussing any other theory. I eventually decided to teach what I considered the most powerful theory first, even though it was neither historically nor logically the first. Students thereafter tended to dismiss other theories out of hand and were impatient to get on the next part of the course. The effort it took to disabuse students of even the weakest theory (stimulus-response behaviorism), if it came first, was enormous. These students were practicing teachers and so, naturally, they did not come to the course with any articulated prior theory of how students learn.

Traditional developmental models, and a lot of empty curricular rhetoric, suggests that either there is a `logical' order or sequence in which topics should be learned, or that there are definite precursor stages through which a learner must pass on the way to some curricular goal. Modern theories of the relation of development and evolution tend to suggest that indeed `ontogeny recapitulates phylogeny', i.e. that developmental trajectories represent cumulations of individual developmental innovations by genetic ancestors. If this model applied directly to education, it would strongly favor a strict historical approach to the teaching of all subjects.

But we know from the successional model that there is actually a great deal more lattitude in the successional trajectory of a juvenile patch that there is in normal embryogenesis. There is in fact no guarantee that, given any freedom at all, students would recapitulate the actual historical development of any particular topic in science or any other subject. If we look at the usual curriculum in science for a topic like the structure of the atom, which tends to be taught quasi-historically, what we find is that (1) students tend to stick with the first model taught in enough detail to become entrenched (planetary electrons), and (2) they are taught a more modern picture (electron orbitals as probability distributions) without any of the actual precursor concepts (wave dynamics, probability density) that historically informed the evolution of this view.

The successional model suggests that some shortcuts that truncate the tortuous path of the actual historical evolution of specific scientific discourses may be perfectly valid, but there will probably still in fact be some (perhaps alternative sets of) necessary precursor concepts (actually thematic formations, discourses) needed to arrive at a target discourse with any real fluency. Very little is known at present about the actual kinds of diversity that occur or could occur in the process of intellectual succession in students' study of various topics in science or other fields. Even less is known about the possible role of specific precursor discourses in these potentially highly diverse successions. Science education, and education more generally, has increasingly taken a fruitless Ends & Means engineering approach to teaching, modelling mass education on mass production. Complex, evolving, developing, self-organizing, highly non-linear systems like ecologies, ecosocial communities, and human groups and individuals do not respond to approaches which so totally misunderstand their nature.

The successional model provides us with one acid test of whether apparent social learning actually represents an active semogenesis (i.e. true development or succession: the reorganization of interconnections in use) or just a superficial, memory-abetted compliance with curricular demands. *Do different patches take different paths and come to different conclusions?* If there is no genuine diversity in its results, 'learning' is a fraud. If all students 'master the curriculum' to our satisfaction, this is no proof of real intellectual development, but rather of its absence. Real thinking by real people always leads to real differences in conclusions. Traditional developmental models embody a principle of equifinality: all roads lead to Rome, to the One Truth, to species-identical adults. That is perhaps why they have been so popular in the most dogmatic of the school subjects: science and mathematics. But such models are bad biology, worse social theory, and educationally untenable. Models from complex system theory that incorporate the kind of variability and dynamical, evolutionary character found in ecological succession should replace them, and the sooner the better.

When science or mathematics, for example, is taught simply as a set of procedures, the curriculum may reasonably expect that all students learn to perform the same procedures in the same way. But then science and mathematics are not being taught as intellectual disciplines or as a part of the liberal arts (cf. AAAS 1990). The body of the science and mathematics curriculum ought to provide the resources whereby students can make their own mathematics, their own science, as scientists and mathematicians do. Science and mathematics education has long endorsed this principle, but refused its curricular (or perhaps anti-curricular) implications. Such a curriculum must expect, promote, and value diversity in students' work and results.

Science education proposes to teach students how to do science for themselves, perhaps even in groups, as explicit members of communities, and this is its ultimate intellectual justification. But the sad fact is that it is only finally when actual doctoral research begins, perhaps after as many as 12 years of soul-crushing science indoctrination in formal school and university coursework, that anybody might even think of mentioning to a student how to go about actually doing science of their own. And from that point on, those very few who remain do in fact start coming to different conclusions.

These have been some of mine.

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