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Connectivism:

A Learning Theory for the Digital Age

December 12, 2004
George Siemens

Update (April 5, 2005): I've added a website to explore this concept at http://www.connectivism.ca/

Introduction

Behaviorism, cognitivism, and constructivism are the three broad learning theories most often utilized in the creation of instructional environments. These theories, however, were developed in a time when learning was not impacted through technology. Over the last twenty years, technology has reorganized how we live, how we communicate, and how we learn. Learning needs and theories that describe learning principles and processes, should be reflective of underlying social environments. Vaill emphasizes that "learning must be a way of being – an ongoing set of attitudes and actions by individuals and groups that they employ to try to keep abreast o the surprising, novel, messy, obtrusive, recurring events…" (1996, p.42).

Learners as little as forty years ago would complete the required schooling and enter a career that would often last a lifetime. Information development was slow. The life of knowledge was measured in decades. Today, these foundational principles have been altered. Knowledge is growing exponentially. In many fields the life of knowledge is now measured in months and years. Gonzalez (2004) describes the challenges of rapidly diminishing knowledge life:

> "One of the most persuasive factors is the shrinking half-life of knowledge. The "half-life of knowledge" is the time span from when knowledge is gained to when it becomes obsolete. Half of what is known today was not known 10 years ago. The amount of knowledge in the world has doubled in the past 10 years and is doubling every 18 months according to the American Society of Training and Documentation (ASTD). To combat the shrinking half-life of knowledge, organizations have been forced to develop new methods of deploying instruction."

Some significant trends in learning:

- Many learners will move into a variety of different, possibly unrelated fields over the course of their lifetime.
- Informal learning is a significant aspect of our learning experience. Formal education no longer comprises the majority of our learning. Learning now occurs in a variety of ways – through communities of practice, personal networks, and through completion of work-related tasks.
- Learning is a continual process, lasting for a lifetime. Learning and work related activities are no longer separate. In many situations, they are the same.
- Technology is altering (rewiring) our brains. The tools we use define and shape our thinking.
- The organization and the individual are both learning organisms. Increased attention to knowledge management highlights the need for a theory that attempts to explain the link between individual and organizational learning.
- Many of the processes previously handled by learning theories (especially in cognitive information processing) can now be off-loaded to, or supported by, technology.
- Know-how and know-what is being supplemented with know-where (the understanding of where to find knowledge needed).

Background

Driscoll (2000) defines learning as "a persisting change in human performance or performance potential…[which] must come about as a result of the learner's experience and interaction with the world" (p.11). This definition encompasses many of the attributes commonly associated with behaviorism, cognitivism, and constructivism – namely, learning as a lasting changed state (emotional, mental, physiological (i.e. skills)) brought about as a result of experiences and interactions with content or other people.

Driscoll (2000, p14-17) explores some of the complexities of defining learning. Debate centers on:

- Valid sources of knowledge - Do we gain knowledge through experiences? Is it innate (present at birth)? Do we acquire it through thinking and reasoning?
- Content of knowledge – Is knowledge actually knowable? Is it directly knowable through human experience?
- The final consideration focuses on three epistemological traditions in relation to learning: Objectivism, Pragmatism, and Interpretivism
    - Objectivism (similar to behaviorism) states that reality is external and is objective, and knowledge is gained through experiences.
    - Pragmatism (similar to cognitivism) states that reality is interpreted, and knowledge is negotiated through experience and thinking.
    - Interpretivism (similar to constructivism) states that reality is internal, and knowledge is constructed.

All of these learning theories hold the notion that knowledge is an objective (or a state) that is attainable (if not already innate) through either reasoning or experiences. Behaviorism, cognitivism, and constructivism (built on the epistemological traditions) attempt to address how it is that a person learns.

Behaviorism states that learning is largely unknowable, that is, we can't possibly understand what goes on inside a person (the "black box theory"). Gredler (2001) expresses behaviorism as being comprised of several theories that make three assumptions about learning:

1. Observable behaviour is more important than understanding internal activities
2. Behaviour should be focused on simple elements: specific stimuli and responses
3. Learning is about behaviour change

Cognitivism often takes a computer information processing model. Learning is viewed as a process of inputs, managed in short term memory, and coded for long-term recall. Cindy Buell details this process: "In cognitive theories, knowledge is viewed as symbolic mental constructs in the learner's mind, and the learning process is the means by which these symbolic representations are committed to memory."

Constructivism suggests that learners create knowledge as they attempt to understand their experiences (Driscoll, 2000, p. 376). Behaviorism and cognitivism view knowledge as external to the learner and the learning process as the act of internalizing knowledge. Constructivism assumes that learners are not empty vessels to be filled with knowledge. Instead, learners are actively attempting to create meaning. Learners often select and pursue their own learning. Constructivist principles acknowledge that real-life learning is messy and complex. Classrooms which emulate the "fuzziness" of this learning will be more effective in preparing learners for life-long learning.

Limitations of Behaviorism, Cognitivism, and Constructivism

A central tenet of most learning theories is that learning occurs inside a person. Even social constructivist views, which hold that learning is a socially enacted process, promotes the principality of the individual (and her/his physical presence – i.e. brain-based) in learning. These theories do not address learning that occurs outside of people (i.e. learning that is stored and manipulated by technology). They also fail to describe how learning happens within organizations

Learning theories are concerned with the actual process of learning, not with the value of what is being learned. In a networked world, the very manner of information that we acquire is worth exploring. The need to evaluate the worthiness of learning something is a meta-skill that is applied before learning itself begins. When knowledge is subject to paucity, the process of assessing worthiness is assumed to be intrinsic to learning. When knowledge is abundant, the rapid evaluation of knowledge is important. Additional concerns arise from the rapid increase in information. In today's environment, action is often needed without personal learning – that is, we need to act by drawing information outside of our primary knowledge. The ability to synthesize and recognize connections and patterns is a valuable skill.

Many important questions are raised when established learning theories are seen through technology. The natural attempt of theorists is to continue to revise and evolve theories as conditions change. At some point, however, the underlying conditions have altered so significantly, that further modification is no longer sensible. An entirely new approach is needed.

Some questions to explore in relation to learning theories and the impact of technology and new sciences (chaos and networks) on learning:

- How are learning theories impacted when knowledge is no longer acquired in the linear manner?
- What adjustments need to made with learning theories when technology performs many of the cognitive operations previously performed by learners (information storage and retrieval).
- How can we continue to stay current in a rapidly evolving information ecology?
- How do learning theories address moments where performance is needed in the absence of complete understanding?
- What is the impact of networks and complexity theories on learning?
- What is the impact of chaos as a complex pattern recognition process on learning?
- With increased recognition of interconnections in differing fields of knowledge, how are systems and ecology theories perceived in light of learning tasks?

An Alternative Theory

Including technology and connection making as learning activities begins to move learning theories into a digital age. We can no longer personally experience and acquire learning that we need to act. We derive our competence from forming connections. Karen Stephenson states:

> "Experience has long been considered the best teacher of knowledge. Since we cannot experience everything, other people's experiences, and hence other people, become the surrogate for knowledge. 'I store my knowledge in my friends' is an axiom for collecting knowledge through collecting people (undated)."

Chaos is a new reality for knowledge workers. ScienceWeek (2004) quotes Nigel Calder's definition that chaos is "a cryptic form of order". Chaos is the breakdown of predictability, evidenced in complicated arrangements that initially defy order. Unlike constructivism, which states that learners attempt to foster understanding by meaning making tasks, chaos states that the meaning exists – the learner's challenge is to recognize the patterns which appear to be hidden. Meaning-making and forming connections between specialized communities are important activities.

Chaos, as a science, recognizes the connection of everything to everything. Gleick (1987) states: "In weather, for example, this translates into what is only half-jokingly known as the Butterfly Effect – the notion that a butterfly stirring the air today in Peking can transform storm systems next month in New York" (p. 8). This analogy highlights a real challenge: "sensitive dependence on initial conditions" profoundly impacts what we learn and how we act based on our learning. Decision making is indicative of this. If the underlying conditions used to make decisions change, the decision itself is no longer as correct as it was at the time it was made. The ability to recognize and adjust to pattern shifts is a key learning task.

Luis Mateus Rocha (1998) defines self-organization as the "spontaneous formation of well organized structures, patterns, or behaviors, from random initial conditions." (p.3). Learning, as a self-organizing process requires that the system (personal or organizational learning systems) "be informationally open, that is, for it to be able to classify its own interaction with an environment, it must be able to change its structure…" (p.4). Wiley and Edwards acknowledge the importance of self-organization as a learning process: "Jacobs argues that communities self-organize is a manner similar to social insects: instead of thousands of ants crossing each other's pheromone trails and changing their behavior accordingly, thousands of humans pass each other on the sidewalk and change their behavior accordingly.". Self-organization on a personal level is a micro-process of the larger self-organizing knowledge constructs created within corporate or institutional environments. The capacity to form connections between sources of information, and thereby create useful information patterns, is required to learn in our knowledge economy.

Networks, Small Worlds, Weak Ties

A network can simply be defined as connections between entities. Computer networks, power grids, and social networks all function on the simple principle that people, groups, systems, nodes, entities can be connected to create an integrated whole. Alterations within the network have ripple effects on the whole.

Albert-László Barabási states that "nodes always compete for connections because links represent survival in an interconnected world" (2002, p.106). This competition is largely dulled within a personal learning network, but the placing of value on certain nodes over others is a reality. Nodes that successfully acquire greater profile will be more successful at acquiring additional connections. In a learning sense, the likelihood that a concept of learning will be linked depends on how well it is currently linked. Nodes (can be fields, ideas, communities) that specialize and gain recognition for their expertise have greater chances of recognition, thus resulting in cross-pollination of learning communities.

Weak ties are links or bridges that allow short connections between information. Our small world networks are generally populated with people whose interests and knowledge are similar to ours. Finding a new job, as an example, often occurs through weak ties. This principle has great merit in the notion of serendipity, innovation, and creativity. Connections between disparate ideas and fields can create new innovations.

Connectivism

Connectivism is the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual. Learning (defined as actionable knowledge) can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing.

Connectivism is driven by the understanding that decisions are based on rapidly altering foundations. New information is continually being acquired. The ability to draw distinctions between important and unimportant information is vital. The ability to recognize when new information alters the landscape based on decisions made yesterday is also critical.

Principles of connectivism:

- Learning and knowledge rests in diversity of opinions.
- Learning is a process of connecting specialized nodes or information sources.
- Learning may reside in non-human appliances.
- Capacity to know more is more critical than what is currently known
- Nurturing and maintaining connections is needed to facilitate continual learning.
- Ability to see connections between fields, ideas, and concepts is a core skill.
- Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.
- Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision.

Connectivism also addresses the challenges that many corporations face in knowledge management activities. Knowledge that resides in a database needs to be connected with the right people in the right context in order to be classified as learning. Behaviorism, cognitivism, and constructivism do not attempt to address the challenges of organizational knowledge and transference.

Information flow within an organization is an important element in organizational effectiveness. In a knowledge economy, the flow of information is the equivalent of the oil pipe in an industrial economy. Creating, preserving, and utilizing information flow should be a key organizational activity. Knowledge flow can be likened to a river that meanders through the ecology of an organization. In certain areas, the river pools and in other areas it ebbs. The health of the learning ecology of the organization depends on effective nurturing of information flow.

Social network analysis is an additional element in understanding learning models in a digital era. Art Kleiner (2002) explores Karen Stephenson's "quantum theory of trust" which "explains not just how to recognize the collective cognitive capability of an organization, but how to cultivate and increase it". Within social networks, hubs are well-connected people who are able to foster and maintain knowledge flow. Their interdependence results in effective knowledge flow, enabling the personal understanding of the state of activities organizationally.

The starting point of connectivism is the individual. Personal knowledge is comprised of a network, which feeds into organizations and institutions, which in turn feed back into the network, and then continue to provide learning to individual. This cycle of knowledge development (personal to network to organization) allows learners to remain current in their field through the connections they have formed.

Landauer and Dumais (1997) explore the phenomenon that "people have much more knowledge than appears to be present in the information to which they have been exposed". They provide a connectivist focus in stating "the simple notion that some domains of knowledge contain vast numbers of weak interrelations that, if properly exploited, can greatly amplify learning by a process of inference". The value of pattern recognition and connecting our own "small worlds of knowledge" are apparent in the exponential impact provided to our personal learning.

John Seely Brown presents an interesting notion that the internet leverages the small efforts of many with the large efforts of few. The central premise is that connections created with unusual nodes supports and intensifies existing large effort activities. Brown provides the example of a Maricopa County Community College system project that links senior citizens with elementary school students in a mentor program. The children “listen to these “grandparents” better than they do their own parents, the mentoring really helps the teachers…the small efforts of the many- the seniors – complement the large efforts of the few – the teachers.” (2002). This amplification of learning, knowledge and understanding through the extension of a personal network is the epitome of connectivism.

Implications

The notion of connectivism has implications in all aspects of life. This paper largely focuses on its impact on learning, but the following aspects are also impacted:

- Management and leadership. The management and marshalling of resources to achieve desired outcomes is a significant challenge. Realizing that complete knowledge cannot exist in the mind of one person requires a different approach to creating an overview of the situation. Diverse teams of varying viewpoints are a critical structure for completely exploring ideas. Innovation is also an additional challenge. Most of the revolutionary ideas of today at one time existed as a fringe element. An organizations ability to foster, nurture, and synthesize the impacts of varying views of information is critical to knowledge economy survival. Speed of “idea to implementation” is also improved in a systems view of learning.
- Media, news, information. This trend is well under way. Mainstream media organizations are being challenged by the open, real-time, two-way information flow of blogging.
- Personal knowledge management in relation to organizational knowledge management
- Design of learning environments

Conclusion:

The pipe is more important than the content within the pipe. Our ability to learn what we need for tomorrow is more important than what we know today. A real challenge for any learning theory is to actuate known knowledge at the point of application. When knowledge, however, is needed, but not known, the ability to plug into sources to meet the requirements becomes a vital skill. As knowledge continues to grow and evolve, access to what is needed is more important than what the learner currently possesses.

Connectivism presents a model of learning that acknowledges the tectonic shifts in society where learning is no longer an internal, individualistic activity. How people work and function is altered when new tools are utilized. The field of education has been slow to recognize both the impact of new learning tools and the environmental changes in what it means to learn. Connectivism provides insight into learning skills and tasks needed for learners to flourish in a digital era.

References

Barabási, A. L., (2002) *Linked: The New Science of Networks*, Cambridge, MA, Perseus Publishing.

Buell, C. (undated). *Cognitivism*. Retrieved December 10, 2004 from http://web.cocc.edu/cbuell/theories/cognitivism.htm.

Brown, J. S., (2002). *Growing Up Digital: How the Web Changes Work, Education, and the Ways People Learn.* United States Distance Learning Association. Retrieved on December 10, 2004, from http://www.usdla.org/html/journal/FEB02_Issue/article01.html

Driscoll, M. (2000). *Psychology of Learning for Instruction.* Needham Heights, MA, Allyn & Bacon.

Gleick, J., (1987). *Chaos: The Making of a New Science.* New York, NY, Penguin Books.

Gonzalez, C., (2004). *The Role of Blended Learning in the World of Technology*. Retrieved December 10, 2004 from http://www.unt.edu/benchmarks/archives/2004/september04/eis.htm.

Gredler, M. E., (2005) *Learning and Instruction: Theory into Practice* – 5th Edition, Upper Saddle River, NJ, Pearson Education.

Kleiner, A. (2002). *Karen Stephenson's Quantum Theory of Trust.* Retrieved December 10, 2004 from http://www.netform.com/html/s+b%20article.pdf.

Landauer, T. K., Dumais, S. T. (1997). *A Solution to Plato's Problem: The Latent Semantic Analysis Theory of Acquisition, Induction and Representation of Knowledge.* Retrieved December 10, 2004 from http://lsa.colorado.edu/papers/plato/plato.annote.html.

Rocha, L. M. (1998). *Selected Self-Organization and the Semiotics of Evolutionary Systems.* Retrieved December 10, 2004 from http://informatics.indiana.edu/rocha/ises.html.

ScienceWeek (2004) Mathematics: Catastrophe Theory, Strange Attractors, Chaos. Retrieved December 10, 2004 from http://scienceweek.com/2003/sc031226-2.htm.

Stephenson, K., (Internal Communication, no. 36) *What Knowledge Tears Apart, Networks Make Whole.* Retrieved December 10, 2004 from http://www.netform.com/html/icf.pdf.

Vaill, P. B., (1996). *Learning as a Way of Being.* San Francisco, CA, Jossey-Blass Inc.

Wiley, D. A and Edwards, E. K. (2002). *Online self-organizing social systems: The decentralized future of online learning.* Retrieved December 10, 2004 from http://wiley.ed.usu.edu/docs/ososs.pdf.

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Editor's Note: The content and technology are continually changing. This article reminds us that learners are also changing. For the past decade, faculty who won awards for teaching expressed concern that they could no longer hold the attention of their students. John Seely Brown, Chief Scientist at Xerox and director of its Palo Alto Research Center, hired 15 year olds to design future work environments and learning environments. He observed that the students did not conform to the traditional image of learners as permissive sponges. It requires us to rethink and redesign education for the Digital Age.

GROWING UP DIGITAL

How the Web Changes Work, Education, and the Ways People Learn

John Seely Brown

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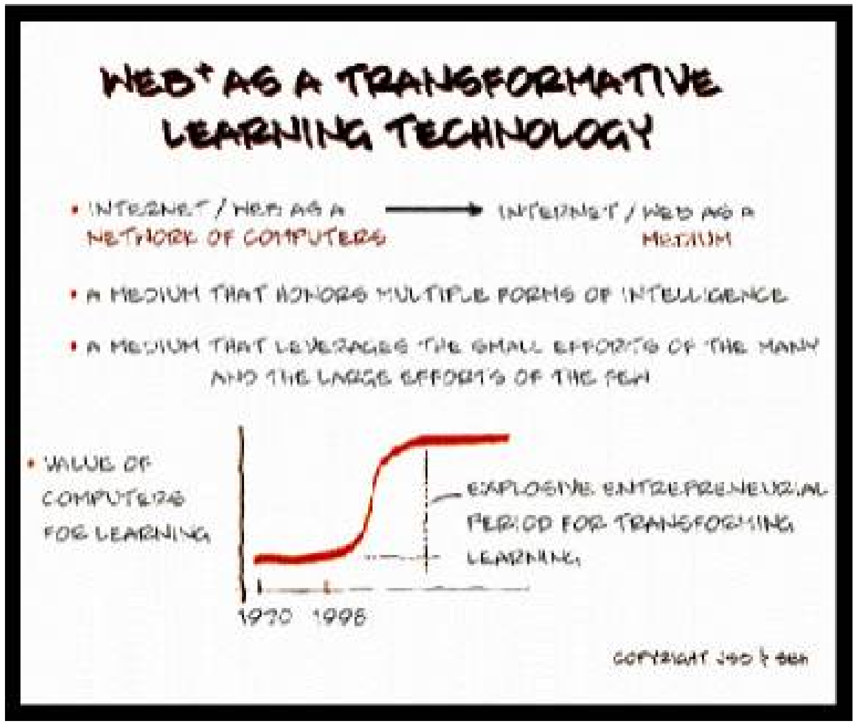
In 1831 Michael Faraday built a small generator that produced electricity, but a generation passed before an industrial version was built, then another 25 years before all the necessary accoutrements for electrification came into place-power companies, neighborhood wiring, appliances (like light bulbs) that required electricity, and so on. But when that infrastructure finally took hold, everything changed-homes, work places, transportation, entertainment, architecture, what we ate, even when we went to bed. Worldwide, electricity became a transformative medium for social practices.



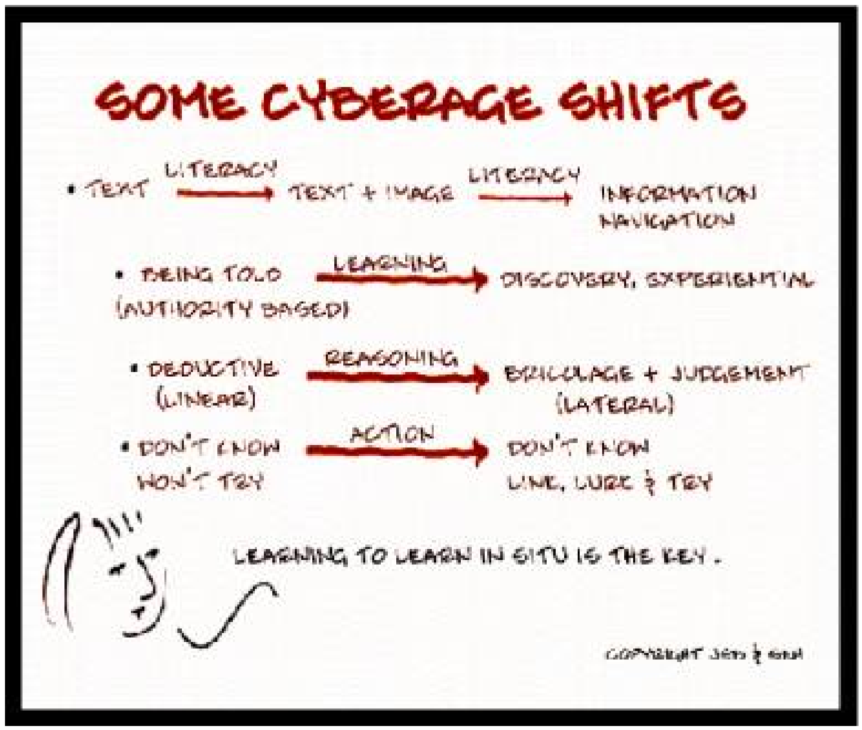
In quite the same way, the World Wide Web will be a transformative medium, as important as electricity. Here again we have a story of gradual development followed by an exploding impact. The Web's antecedents trace back to a U.S. Department of Defense project begun in the late 1960s, then to the innovations of Tim Berners-Lee and others at the Center for European Nuclear Research in the late 1980s, followed by rapid adoption in the mid- and late-1990s. Suddenly we had e-mail available, then a new way to look up information, then a remarkable way to do our shopping-but that's barely the start. The tremendous range of transformations wrought by electricity, so barely sensed by our grandparents a century ago, lie ahead of us through the Web.

No one fully knows what those transformations will be, but what we do know is that initial uses of new media have tended to mimic what came before: early photography imitated painting, the first movies the stage, etc. It took 10 to 20 years for filmmakers to discover the inherent capabilities of their new medium. They were to develop techniques now commonplace in movies, such as "fades," "dissolves," "flashbacks," "time and space folds," and "special effects," all radically different from what had been possible in the theater. So it will be for the Web. What we initially saw as an intriguing network of computers is now evolving its own genres from a mix of technological possibilities and social and market needs.

Challenging as it is, this article will try to look ahead to understand the Web's fundamental properties; see how they might create a new kind of information fabric in which learning, working, and playing co-mingle; examine the notion of distributed intelligence; ask how one might better capture and leverage naturally occurring knowledge assets; and finally get to our core topic-how all of this might fold together into a new concept of "learning ecology." Along the way, too, we'll look frequently at learning itself and ask not only how it occurs now, but how it can become ubiquitous in the future.

A New Medium

The first thing to notice is that the media we're all familiar with-from books to television-are one-way propositions: they push their content *at* us. The Web is two-way, push *and pull.* In finer point, it combines the one-way reach of broadcast with the two-way reciprocity of a mid-cast. Indeed, its user can at once be a receiver and sender of "broadcast"-a confusing property, but mind-stretching!



A second aspect of the Web is that it is the first medium that honors the notion of multiple intelligences. This past century's concept of "literacy" grew out of our intense belief in text, a focus enhanced by the power of one particular technology-the typewriter. It became a great tool for writers but a terrible one for other creative activities such as sketching, painting, notating music, or even mathematics. The typewriter prized one particular kind of intelligence, but with the Web, we suddenly have a medium that honors multiple forms of intelligence-abstract, textual, visual, musical, social, and kinesthetic. As educators, we now have a chance to construct a medium that enables all young people to become engaged in their ideal way of learning. The Web affords the match we need between a medium and how a particular person learns.

A third and unusual aspect of the Web is that it leverages the small efforts of the many with the large efforts of the few. For example, researchers in the Maricopa County Community College system in Phoenix have found a way to link a set of senior citizens with pupils in the Longview Elementary School, as helper-mentors. It's wonderful to see-kids listen to these "grandparents" better than they do to their own parents, the mentoring really helps their teachers, and the seniors create a sense of meaning for themselves. Thus, the small efforts of the many-the seniors-complement the large efforts of the few-the teachers.

The same thing can be found in operation at Hewlett-Packard, where engineers use the Web to help kids with science or math problems. Both of these examples barely scratch the surface as we think about what's possible when we start interlacing resources with needs across a whole region.

The Web has just begun to have an impact on our lives. As fascinated as we are with it today, we're still seeing it in its early forms. We've yet to see the full motion video and audio possibilities that await the bandwidth we'll soon have through cable modems and DSL; also to come are the new Web appliances, such as the portable Web in a phone, and a host of wireless technologies. As important as any of these is the imagination, competitive drive, and capital behind a thousand companies-chased by a swelling list of dot-coms-rushing to bring new content, services, and "solutions" to offices and homes.

My belief is that not only will the Web be as fundamental to society as electrification, but that it will be subject to many of the same diffusion and absorption dynamics as that earlier medium. We're just at the bottom of the S -curve of this innovation, a curve that will have about the same shape as with electrification, but a much steeper slope than before. As this S-curve takes off, it creates huge opportunities for entrepreneurs. It will be entrepreneurs, corporate or academic, who will drive this chaotic, transformative phenomenon, who will see things differently, challenge background assumptions, and bring new possibilities into being. Our challenge and opportunity, then, is to foster an entrepreneurial spirit toward creating new *learning* environments-a spirit that will use the unique capabilities of the Web to leverage the natural ways that humans learn.

Digital Learners

Let's turn to today's youth, growing up digital. How are they different? This subject matters, because our young boys and girls are today's customers for schools and colleges and tomorrow's for lifelong learning. Approximately four years ago, we at Xerox's Palo Alto Research Center started hiring 15 year olds to join us as researchers. We gave them two jobs. First, they were to design the "workscape" of the future-one they'd want to work in; second, they were to design the school or "learningscape" of the future-again, with the same condition. We had an excellent opportunity to watch these adolescents, and what we saw the ways they think, the designs they came up with-really shook us up.

For example, today's kids are always "multiprocessing"-they do several things simultaneously-listen to music, talk on the cell phone, and use the computer, all at the same time. Recently I was with a young twenty-something who had actually wired a Web browser into his eyeglasses. As he talked with me, he had his left hand in his pocket to cord in keystrokes to bring up my Web page and read about me, all the while carrying on with his part of the conversation! I was astonished that he could do all this in parallel and so unobtrusively.

People my age tend to think that kids who are multiprocessing can't be concentrating. That may not be true. Indeed, one of the things we noticed is that the attention span of the teens at PARC-often between 30 seconds and five minutes-parallels that of top managers, who operate in a world of fast context-switching. So the short attention spans of today's kids may turn out to be far from dysfunctional for future work worlds.

Let me bring together our findings by presenting a set of dimensions, and shifts along them, that describe kids in the digital age. We present these dimensions in turn, but they actually fold in on each other, creating a complex of intertwined cognitive skills.

The first dimensional shift has to do with literacy and how it is evolving. Literacy today involves not only text, but also image and screen literacy. The ability to "read" multimedia texts and to feel comfortable with new, multiple-media genres is decidedly nontrivial. We've long downplayed this ability; we tend to think that watching a movie, for example, requires no particular skill. If, however, you'd been left out of society for 10 years and then came back and saw a movie, you'd find it a very confusing, even jarring, experience. The network news shows-even the front page of your daily newspaper-are all very different from 10 years ago. Yet Web genres change in a *period of* months.

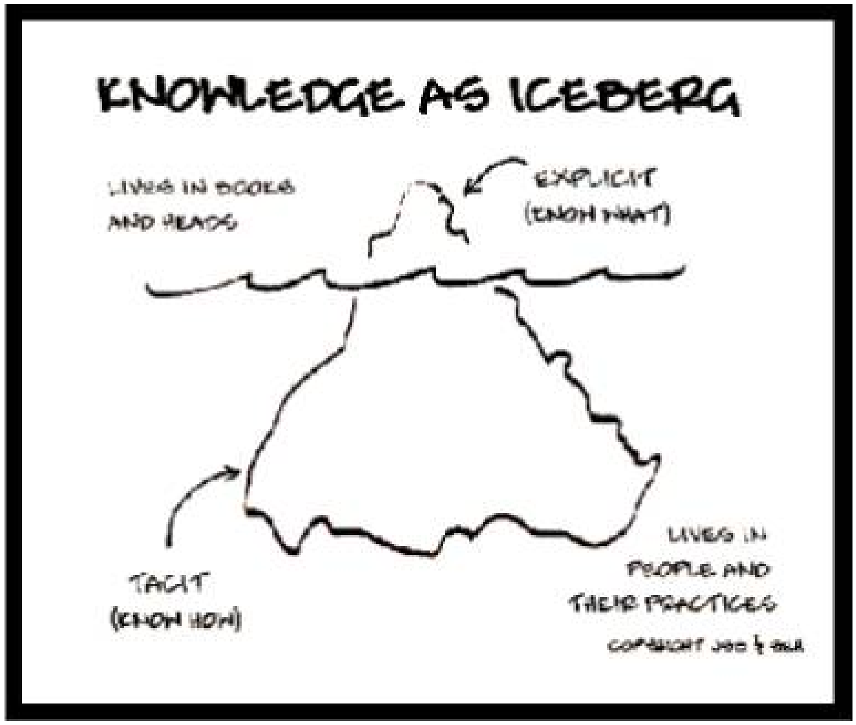
The new literacy, beyond text and image, is one of information navigation. The real literacy of tomorrow entails the ability to be your own personal reference librarian-to know how to navigate through confusing, complex information spaces and feel comfortable doing so. "Navigation" may well be the main form of literacy for the 21st century.

The next dimension, and shift, concerns learning. Most of us experienced formal learning in an authority-based, lecture-oriented school. Now, with incredible amounts of information available through the Web, we find a "new" kind of learning assuming pre-eminence-learning that's discovery based. We are constantly discovering new things as we browse through the emergent digital "libraries." Indeed, Web surfing fuses learning and entertainment, creating "infotainment."

But discovery-based learning, even when combined with our notion of navigation, is not so great a change, until we add a third, more subtle shift, one that pertains to forms of reasoning. Classically, reasoning has been concerned with the deductive and abstract. But our observation of kids working with digital media suggests *bricolage* to us more than abstract logic. *Bricolage,* a concept studied by Claude Levi-Strauss more than a generation ago, relates to the concrete. It has to do with abilities to find something-an object, tool, document, a piece of code-and to use it to build something you deem important. *Judgment* is inherently critical to becoming an effective digital *bricoleur*.

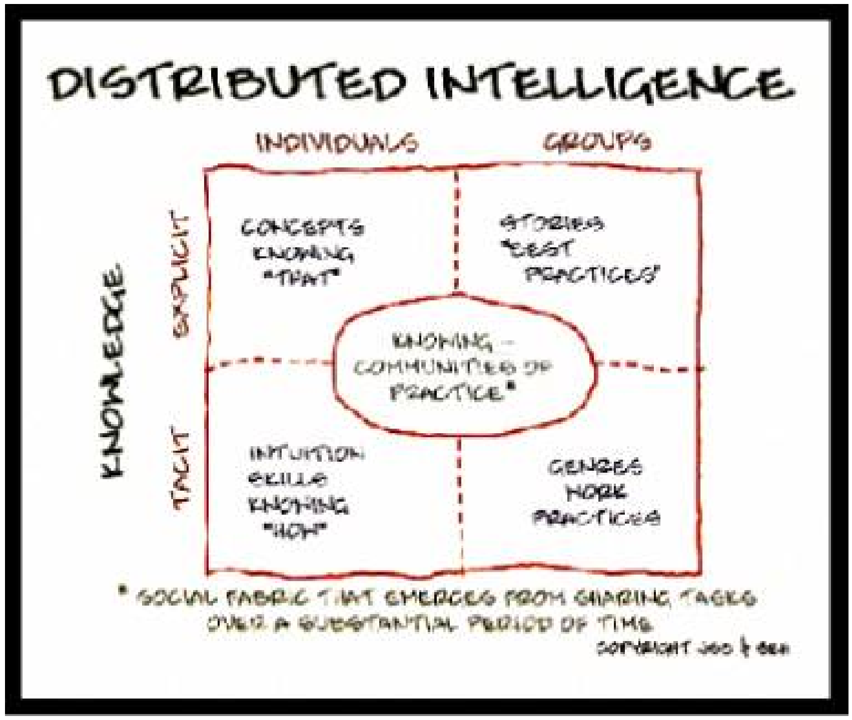
How do we make good judgments? Socially, in terms of recommendations from people we trust? Cognitively, based on rational argumentation? On the reputation of a sponsoring institution? What's the mixture of ways and warrants that you end up using to decide and act? With the Web, the sheer scope and variety of resources befuddles the non-digital adult. But Web-smart kids learn to become *bricoleurs.*

The final dimension has to do with a bias toward action. It's interesting to watch how new systems get absorbed by society; with the Web, this absorption, or learning process, by young people has been quite different from the process in times past. My generation tends not to want to try things unless or until we already know how to use them. If we don't know how to use some appliance or software, our instinct is to reach for a manual or take a course or call up an expert. Believe me, hand a manual or suggest a course to 15 year olds and they think you are a dinosaur. They want to turn the thing on, get in there, muck around, and see what works. Today's kids get on the Web and link, lurk, and watch how other people are doing things, then try it themselves. This tendency toward "action" brings us back into the same loop in which navigation, discovery, and judgment all come into play *in situ*. When, for example, have we lurked enough to try something ourselves? Once we fold action into the other dimensions, we necessarily shift our focus toward learning *in situ* with and from each other. Learning becomes situated in action; it becomes as much social as cognitive, it is concrete rather than abstract, and it becomes intertwined with judgment and exploration. As such, the Web becomes not only an informational and social resource but a learning *medium* where understandings are socially constructed and shared. In that medium, learning becomes a part of action and knowledge creation.



Creating Knowledge

To see how all these dimensions work, it's necessary to look at knowledge-its creation and sharing-from both the standard Cartesian position and that of the *bricoleur*. Knowledge has two dimensions, the explicit and tacit. The explicit dimension deals with concepts-the "know-whats"-whereas the tacit deals with "know-how," which is best manifested in work practices and skills. Since the tacit lives in action, it comes alive in and through doing things, in participation with each other in the world. As a consequence, tacit knowledge can be distributed among people as a shared understanding that emerges from working together, a point we will return to.



The developmental psychologist Jerome Bruner made a brilliant observation years ago when he said we can teach people about a subject matter like physics-its concepts, conceptual frameworks, its facts-and provide them with explicit knowledge of the field, but *being* a physicist involves a lot more than getting all the answers right at the end of each chapter. To be a physicist, we must also learn the practices of the field, the tacit knowledge in the community of physicists that has to do with things like what constitutes an "interesting" question, what proof may be "good enough" or even "elegant," the rich interplay between facts and theory-formation, and so on. Learning to be a physicist (as opposed to learning about physics) requires cutting a column down the middle of the diagram, looking at the deep interplay between the tacit and explicit. That's where deep expertise lies. Acquiring this expertise requires learning the explicit knowledge of a field, the practices of its community, and the interplay between the two. And learning all this requires immersion in a community of practice, enculturation in its ways of seeing, interpreting, and acting.

The epistemic landscape is more complicated yet because both the tacit and explicit dimensions of knowledge apply not only to the individual but also to the social mind to what we've called communities of practice. It's common for us to think that all knowledge resides in individual heads, but when we factor in the tacit dimension-especially as it relates to practices-we quickly realize how much more we can know than is bounded by our own knowledge. Much of knowing is brought forth in action, through participation-in the world, with other people, around real problems. A lot of our know-how or knowing comes into being through participating in our community(ies) of practice.

Understanding how intelligence is distributed across a broader matrix becomes increasingly critical if we want to leverage "learning to learn," because learning to learn happens most naturally when you and a participant are situated in a community of practice. Returning to Bruner's notion of learning to be, recall that it always involves processes of enculturation. Enculturation lies at the heart of learning. It also lies at the heart of knowing. Knowing has as much to do with picking up the genres of a particular profession as it does with learning its facts and concepts.

Curiously, academics' values tend to put theory at the top in importance, with the grubbiness of practice at the bottom. But think about what you do when you get a PhD. The last two years of most doctoral programs are actually spent in close work with professors, *doing* the discipline with them; these years in effect become a cognitive apprenticeship. Note that this comes after formal course work, which imparted relevant facts and conceptual frameworks. Those frameworks act as scaffolding to help structure the practice developed through the apprenticeship. So learning *in situ* and cognitive apprenticeship fold together in this notion of distributed intelligence.

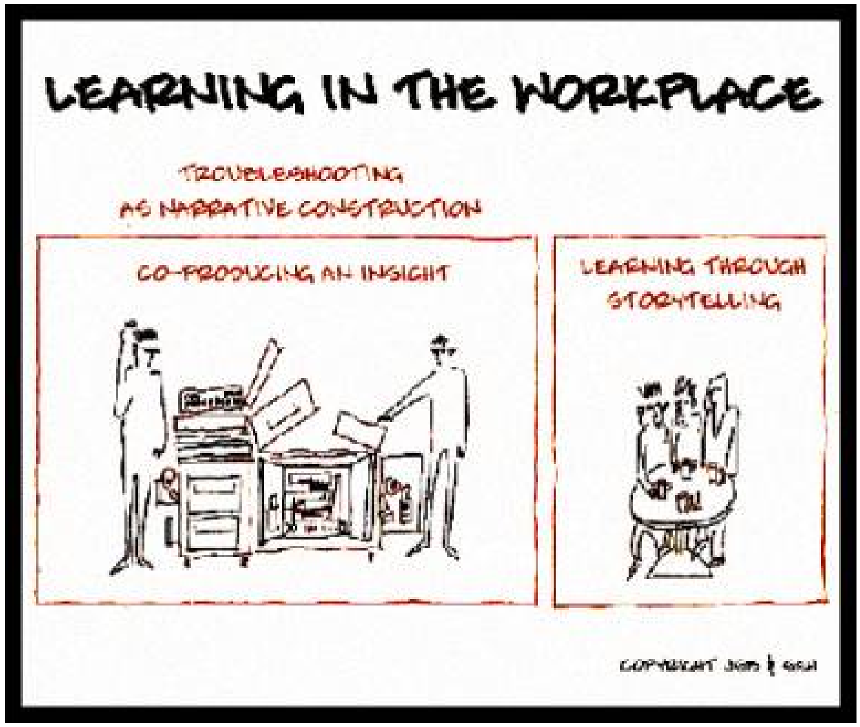
I dwell on this point because each of us has various techniques, mostly invisible, that we use day in and day out to learn with and from each other *in situ*. This is seen all the time on a campus, where students develop techniques for learning that span in-class and out-of-class experiences-all of campus life is about learning how to learn. Colleges should appreciate and support such learning; the key to doing so lies in understanding the dynamic flow in our two-by-two matrix.

If we could use the Web to support the dynamics across these quadrants, we could create a new fabric for learning, for learning to learn *in situ*, for that is the essence of lifelong learning.

Repairing Photocopiers

Talk about a "two-by-two conceptual framework of distributed intelligence" can be terribly abstract; let me bring this to life, and move our argument ahead, with a story from the company where I work. When I arrived at Xerox, back in the 1980s, the company was spending millions and millions of dollars a year training its 23,000 "tech reps" around the world-the people who repair its copiers and printers. Lots of that training-it was like classroom instruction seemed to have little effect. Xerox wanted me to come up with some intelligent-tutoring or artificial-intelligence system for teaching these people troubleshooting. Fortunately, before we did so, we hired several anthropologists to go live in their "tribe" and see how they actually worked.

What the anthropologists learned surprised us. When a tech rep got stuck by a machine, he or she didn't look at the manual or review the training; he or she called another tech rep. As the two of them stood over the problematic machine, they'd recall earlier machines and fixes, then connect those stories to a new one that explained some of the symptoms. Some fragment of the initial story would remind them of another incident, which suggested a new measurement or tweak, which reminded them of another story fragment and fix to try, and so on. Troubleshooting for these people, then, really meant construction of a narrative, one that finally explained the symptoms and test data and got the machine up and running again. Abstract, logical reasoning wasn't the way they went about it; stories were.



This example demonstrates the crucial role of tacit knowledge (in the form of stories) within a community of practice (the tech reps). But the anthropologists had more to tell us. What happened to these stories? When the reps got back to the home office, awaiting the next call, they'd sit around and play cribbage, drink coffee, and swap war stories. Amazing amounts of learning were happening in the telling and hearing of these stories. In the telling, a story got refined, added to, argued about, and stored away for use.

Today, brain scientists have helped us understand more about the architecture of the mind and how it is particularly well suited to remembering stories. That's the happy part. The sad part is that some Xerox executives thought storytelling had to be a waste of time; big posters told the reps, "Don't tell war stories!" Instead, people were sent back for more training. When people returned from it, what did they do? Tell stories about the training, of course, in attempts to transform what they'd been told into something more useful.

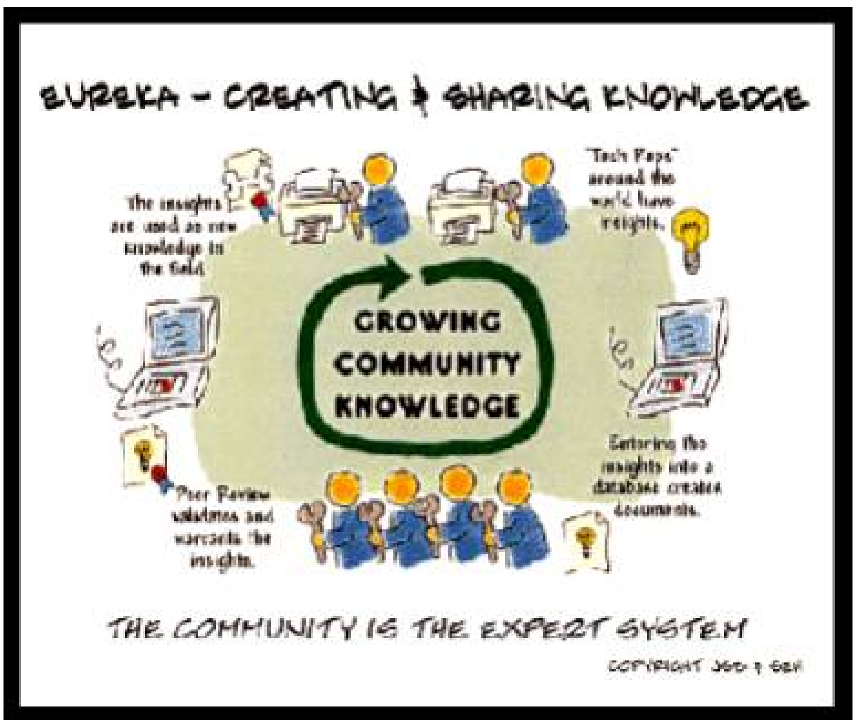
Let me add here that these studies convinced us that for powerful learning to occur, you had to look to both the cognitive and the social dimensions. They also led us to ask, How can we leverage this naturally occurring learning?

Our answer to that question was simple: two-way radios. We gave everybody in our tech rep "community of practice" test site a radio that was always on, with their own private network. Because the radios were al-ways on, the reps were constantly in each other's periphery. When somebody needed help, other tech reps would hear him struggling; when one of them had an idea, he or she could move from the periphery to the (auditory) center, usually to suggest some test or part to replace, adding his or her fragment to an evolving story. Basically, we created a multiperson storytelling process running across the test site. It worked incredibly well.

In fact, it also turned out to be a powerful way to bring new technicians into this community. A novice could lurk on the periphery and hear what was going on, learn from it, maybe ask a question, and eventually make a suggestion when he or she had something to contribute. In effect, the newcomer was a cognitive apprentice, moving from lurker to contributor, very much like today's digital kids on the Web.

The trouble with this scenario is that all these story fragments were being told through the ether, and hence were lost to those reps not participating at the moment. Some of these fragments were real gems! So we needed to find a way to collect, vet, refine, and post them on a community knowledge server. Furthermore, we realized that no one person was the expert; the real expertise resided in the community mind. If we could find a way to support and tap the collective minds of the reps, we'd have a whole new way to accelerate their learning and structure the community's knowledge assets in the making. We wanted to accomplish this, too, with virtually no overhead.

The answer for us was a new, Web-based system called Eureka, which we've had in use for two years now. The interesting thing is that the tech reps, in co-designing this system to make their ideas and stories more actionable, unwittingly reinvented the sociology of science. In reality, they knew many of the ideas and story fragments that floated around were not trustworthy; they were just opinions, sometimes crazy. To transform their opinions and experiences into "warranted" beliefs, hence actionable, contributors had to submit their ideas for peer review, a process facilitated by the Web. The peers would quickly vet and refine the story, and connect it to others. In addition, the author attaches his or her name to the resulting story or tip, thus creating both intellectual capital and social capital, the latter because tech reps who create really great stories become local heroes and hence more central members of their community of practice.



This system has changed the learning curve of our tech reps by 300 percent and will save Xerox about $100 million a year. It is also, for our purposes here, a beautiful example of how the Web enables us to capture and support the social mind and naturally occurring knowledge assets.

Building Knowledge Assets

What are some other emergent ideas-in the workplace or on campus-that might help us capture, refine, and share knowledge assets in the making? Are there ways to capture as sets that are left just lying on the table, as it were, and use them to make learning more productive in classrooms, firms, even a region? The answer, now, is yes. Here are two examples, among many I've seen around the country, especially as entrepreneurs start to see this as ripe territory.

The first example I encountered was at Stanford University. It comes from Professor Jim Gibbons, the former dean of engineering. He discovered the basis of building knowledge assets accidentally some years ago and has been refining it since. Jim had been teaching an engineering course that enrolled several Hewlett-Packard people. Partway through the course, the H-P students were transferred and were no longer physically able to come to class. What Jim did was simply videotape the classes and send them the tapes.

The twist, though, is that once the engineers received the video they'd replay it in their own small study group, but in a special way. Every three minutes or so they'd stop the tape and talk about what they'd just seen, ask each other if there were any questions or ambiguities, and resolve them on the spot. Forward they would go, a few minutes at a time, with lots of talk and double-checking, until they were through the tape and everybody understood the whole lesson. What they were doing, in terms we used earlier, was socially constructing their own meaning of the material.

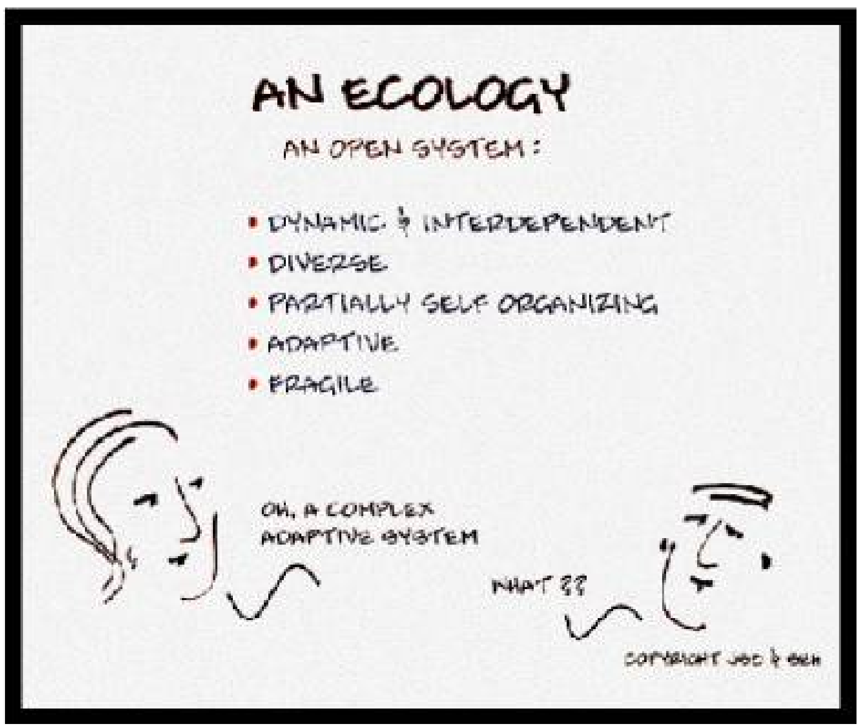
The results were that students taking the course this way outperformed the ones actually taking the classes live. Today, the approach has been tried with other H-P engineers, with college students, even with California prison inmates; most of the students who've tried it got half a grade point better grades than the regular students. This account is not meant as a commentary on regular Stanford classes! Rather, it is used to describe an elegantly simple idea, low-tech and low-cost, about how forming study groups and letting them socially construct their own understanding around a naturally occurring knowledge asset the lecture-turns out to be an amazingly powerful tool for learning. Think about what this suggests for distance learning-or for on-campus students.

The second example stems from research being done both at PARC and Cornell University. The PARC system is called Madcap and looks to see how we might leverage a knowledge asset, our weekly forums, where we often get some wonderful outside speakers. These forum events have proved a valuable stimulus to the whole Silicon Valley region. Of course we make videotapes and give them to people who miss a session. In reality, though, hardly anyone ever replays the tapes because it's very hard to skim through a video stream for the highlights you want. So we asked, Might it be possible to use computers to automatically segment and highlight a video stream? Perhaps even summarize it?

We now have a prototype system for doing this designed by Dan Russell's group at PARC. First we capture and store the digital video on a media server, which also marks and time-stamps any uniquely identifiable event such as clapping, laughing, a slide change, and so on. Audience members can also use their laptops or Palm Pilots to take notes; these can be time-stamped and thus cross-indexed into the video stream. We also transcribe the audio stream. All these "signals" are combined to make a soup of streams, all cross-indexed with each other. The resulting mixture becomes a very rich medium in which it's possible to skim and pick out highlights on your own. Or you can spot where a colleague made an annotation, see and hear the moment, then see what he or she thought about it.

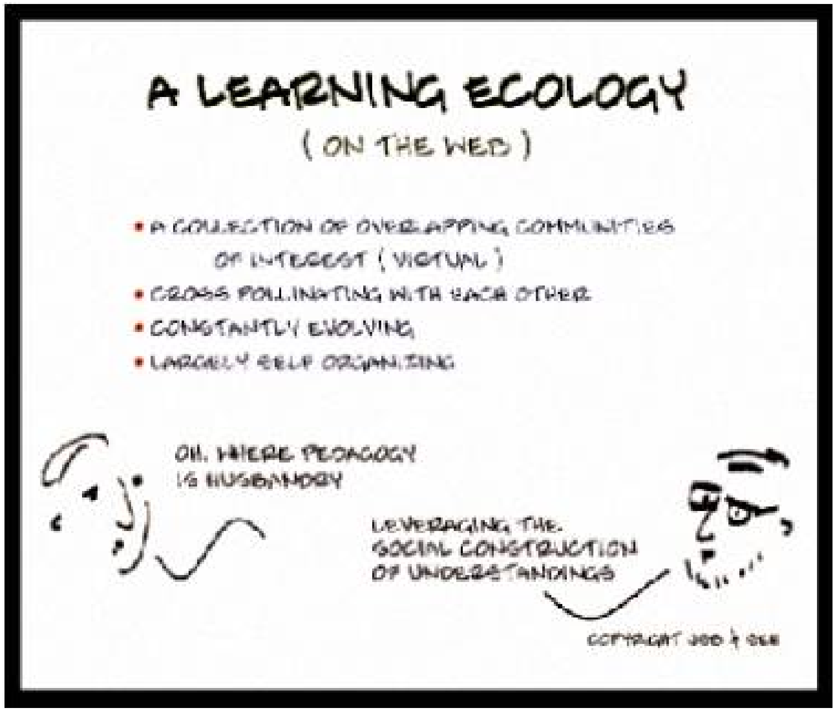
This last point intrigues us: can you capture the additional signals generated by the audience-the notes, approvals, or disagreements recorded as the lecture progressed and use these signals as structural indices to the video stream? The goal is to make this a richer knowledge asset than just the video alone, so that browsing, reflection, and focused conversations are more likely to happen. If you have a diverse set of individuals taking notes and they are willing to identify themselves, you start to create an ecology of annotations-diverse, overlapping, richly opinionated.

The goal, again, is to transform a lecture-a fleeting performance that only some people will experience-into a knowledge asset and tool for deeper learning among a greater number of people. At Cornell, Dan Hattenlocher's research team has added dual video cameras to the mix, one on the lecturer and one that zooms in on the student posing a question, to further enrich the segmenting and indexing of material on the tape. At PARC and Cornell alike, the aim of these tag structures is to transform the lecture into a more structured and useful knowledge asset. Of course this new asset, when viewed and vetted by subsequent audiences, becomes part of another knowledge performance (and knowledge sharing), leading to additional layers of cumulative annotation as its meaning gets further socially constructed.



Toward a Learning Ecology

An ecology is basically an open, complex, adaptive system comprising elements that are dynamic and interdependent. One of the things that makes an ecology so powerful and adaptive to new environments is its diversity. Recall that with the prior examples of knowledge performances, it was the diversity of comments that gave texture to the knowledge asset and enabled it to be used in ways that might never have been originally imagined.



Let's consider a learning ecology, particularly one that might form around or on the Web. As a start down this path, consider the Web as comprising a vast number of "authors" who are members of various interest groups, many of which embody a lot of expertise in both written and tacit form. Given the vastness of the Web, it's easy these days to find a niche community with the expertise you need or a special interest group whose interests coincide exactly with your own.

Recall the famous *New Yorker* cartoon of a dog in front of a computer, saying, "On the `Net nobody knows you are a dog." Online, a kid need not necessarily reveal himself as a kid. Indeed, I've watched a seven year old from New York have a conversation about penguins with an expert at a university in another state. The professor may have sensed that the person he was talking with wasn't a real expert on penguins, but he probably didn't know he was communicating with a second-grader, either. Furthermore, at this child's school there was no one, including his teachers, who shared his interest in penguins. He found the right interest group through navigation. He linked, he lurked, he finally asked a question, and had this brief conversation with an expert. And I can tell you, the professor's momentary effort truly inspired him.

With the Web, these virtual communities of niche interests spread around the world as they interweave with local, face-to-face groups, in school or outside. A new, powerful fabric for learning starts to emerge, drawing strength from the local and the global. A cross-pollination of ideas happens as local students, participating in different virtual communities, carry ideas back and forth between those communities and their local ones.

Now recall our emphasis that informal learning often involves the joint construction of understanding around a focal point of interest, and one begins to sense how these cross-linked interest groups, both real and virtual, form a rich ecology for learning. Of course not all these conversations, even if focused and well intended, lead to productive learning. As we said earlier in discussing digital kids, judgment, navigation, discernment, and synthesis become more critical than ever.

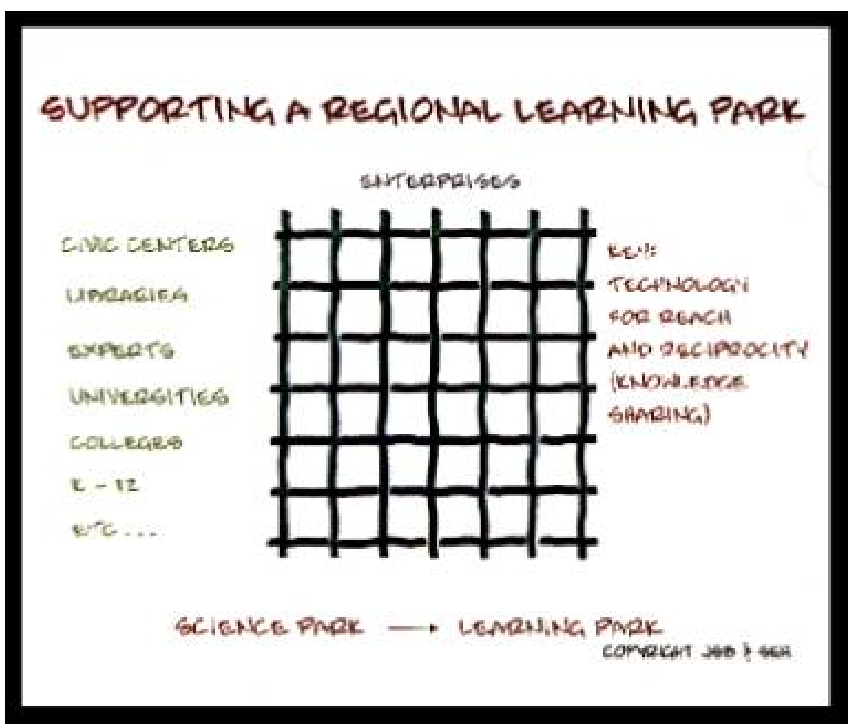
Regional Learning

I've been struck, living in Silicon Valley and spending time in other high-tech regions, by how each region can be analyzed with respect to the quality and diversity of its knowledge producers and knowledge consumers.

The classic way to view knowledge production in a region is to list all the educational institutions one can think of-universities and colleges, schools, libraries, museums, civic centers-and to see these as the region's *producers* of knowledge, with the region's citizens, students, firms, government, and voluntary organizations as their con*sumers.* The matrix on this page represents that relationship.

But in most regions I visit today, there is a rich interplay between the matrix's two axes, albeit one that seldom gets noticed. If the region is geographically compressed enough, you start to get all kinds of informal, face-to-face connections between knowledge producers and consumers-students work part-time in surrounding firms, new firms spin out of universities, employees are retrained on campus, different people frequent common hang-outs, and so on and on. In the 1970s and 1980s we were preoccupied with science parks; in the 1990s, all these connections produce what I think of as learning parks. Such learning parks bring increasingly rich intellectual and educational opportunities to their region.

If top-quality schools and universities once primed the pump for science parks, we now see learning parks pushing resources the other way. In the relation between leading-edge firms and universities, for example, the firms increasingly provide adjunct professors, guest lectures, thesis supervision, internships for students, sabbaticals for faculty, and workplace experiences for scholars of all ages. So the traditional producers of knowledge (the faculty) are also becoming consumers of the knowledge that their traditional consumers (graduate students, firms in the region) produce. This is very healthy, indeed.



Now let's overlay on top of this physical-social region the Web, and look back to the example of students participating in local, face-to-face groups but tying also into virtual ones. A key understanding is that on the Web there seldom is such a thing as just a producer or just a consumer; on the Web, each of us is part consumer and part producer. We read and we write, we absorb and we critique, we listen and we tell stories, we help and we seek help. This is life on the Web. The boundaries be-tween consuming and producing are fluid, which is the secret to many of the business models of Web-based commerce.

From a region's standpoint, the great opportunity here is that the Web helps establish a culture that honors the fluid boundaries between the production and consumption of knowledge. It recognizes that knowledge can be produced wherever serious problems are being attacked and followed to their root. Furthermore, with the Web it is easier for various experts to interact casually-in the academy or in the firm-and to mentor or advise students of any age. On top of this, the Web's great reach provides infinite access to resources beyond the region. The power of this reach comes fully into play when Web resources act to cross-pollinate and provide new points of view for a region's communities of practice.

Within a region, the Web can significantly augment the knowledge dynamics created by proximity. The Web helps build a rich fabric that combines the small efforts of the many with the large efforts of the few. By enriching the diversity of available information and expertise, it enables the culture and sensibilities of a region to evolve. It increases the intellectual density of cross-linkages. It allows anyone to lurk and learn. Indeed its message is that learning can and should be happening everywhere-a learning ecology. All together, a new, self-catalytic system starts to emerge, reinforcing and extending the core competencies of a region.

Let me end with a brief reflection on an interesting shift that I believe is happening: a shift between using technology to support the individual to using technology to support relationships between individuals. With that shift, we will discover new tools and social protocols for helping us help each other, which is the very essence of social learning. It is also the essence of lifelong learning a form of learning that learning ecologies could dramatically facilitate. And developing learning ecologies in a region is a first, important step toward a more general culture of learning.

RESOURCES

John Seely Brown's earlier work on "situated learning" came to notice in a series of widely cited journal articles:

Brown, J.S., A. Collins, and P. Duguid. "Situated Cognition and the Culture of Learning," *Educational Researcher, Vol.* 18, No. 1, 1989, pp. 32-42.

Brown, J.S. and P. Duguid, "Organizational Learning and Communities-of-Practice: Toward a Unified View of Working, Learning, and Innovation," *Organizational Science, Vol.* 2, No. 1, 1991, pp. 40-57.

Collins, A., J.S. Brown, and A. Holum, "Cognitive Apprenticeship: Making Thinking Visible," *American Educator, Vol.* 15, No. 3,1991, pp. 6-11, 38-46.

In 1993, these ideas were pulled together and critiqued in a special issue of *Educational Technology* 33, Vol. 3, which includes a further Brown-Duguid contribution on "Stolen Knowledge" (pp.10-15).

In 1996, Brown and Duguid's ideas about learning formed a centerpiece of their initial contribution to *Change*, "Universities in the Digital Age" (Vol. 28, No. 4,1996, pp. 10-19), which came to be one of the magazine's most widely read and cited pieces.

Many ideas from that and their current *Change* article appear in Brown and Duguid's splendid new book, *The Social Life of Information* (Cambridge: Harvard Business School Press, 2000).

About the Author:

John Seely Brown is the chief scientist of Xerox and director of its Palo Alto Research Center. In 1987, Brown helped found the Institute for Research on Learning (IRL), located in Menlo Park, California, a "research-in-action" think tank that probes "successful everyday learning." Brown and Duguid acknowledge their debt to IRL colleagues for insight and critique that found its way into this article, and particularly to Susan Stucky and Peter Henschel for their two-by-two "distributed intelligence" chart.

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Selected Self-Organization and the Semiotics of Evolutionary Systems

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This paper is available in Adobe Acrobat (.pdf) format. This html version may be missing some special symbols, which you can get with the pdf version.

Abstract: In this paper I sketch a rough taxonomy of self-organization which may be of relevance in the study of cognitive and biological systems. I frame the problem both in terms of the language of second- order cybernetics as well as the language of current theories of self-organization and complexity. The goal of establishing such a taxonomy is to allow for a classification of different tools used both in Artificial Intelligence and Artificial Life, so that different aspects of cognitive and biological systems may be incorporated in more accurate models of such systems. In particular, I defend, on the one hand, that self-organization alone is not rich enough for our intended simulations, and on the other, that genetic selection in biology and symbolic representation in cognitive science alone leave out the very important (self-organizing) characteristics of particular embodiments of evolving and learning systems.

Keywords: Self-organization, Semantic Closure, Semiotics, Emergence, Evolutionary Strategies, Artificial Life, Artificial Intelligence.

1 Eigenbehavior and Emergent Representation

Heinz von Foerster [1965, 1969, 1977] equated the ability of an organization to classify its environment with the notion of *eigenbehavior*. He postulated the existence of some stable structures (*eigenvalues*) which are maintained in the operations of an organization's dynamics. Following Piaget [von Foerster, 1977], he observed that any specific instance of observation of such an organization, will still be the result of an indefinite succession of cognitive/sensory-motor operations. This reiterated the constructivist position that observables do not refer directly to real world objects, but are instead the result of an infinite cascade of cognitive and sensory-motor operations in some environment/subject coupling. Eigenvalues are self-defining, or self-referent, through the imbedding dynamics _ implying a complementary relationship (circularity, closure) between eigenvalues and cognitive/sensory-motor operators: one implies, or defines, the other. "Eigenvalues *represent* the externally observable manifestations of the (introspectively accessible) cognitive [operations]". [von Foerster, 1977, page 278, italics added]. Further, "Ontologically, Eigenvalues and objects, and likewise, ontogenetically, stable behavior and the manifestation of a subject's 'grasp' of an object cannot be distinguished." [von Foerster, 1977, page 280]. *Eigenbehavior* is thus used to define the behavior of autonomous, cognitive systems, which through the closure (self-referential recursion) of the sensory-motor interactions in their nervous systems, give rise to perceptual regularities as objects [Varela, 1979, chapter 13].

"Eigenvalues are discrete (even if the domain of [their observables] is continuous)". In other words, even if the domain of an observable is continuous, its cognitive representation through cognitive/sensory-motor operators into eigenvalues must be discrete. This is a result of the stability of eigenvalues in the recursive chain of cognitive operators, if an eigenvalue changes its structure, thus ending the frame of stability, it will either revert to unstable structures (varying at each cognitive operation), in which case the eigenvalue representation is lost, or form another frame of stability with a new eigenvalue representation. Insummary, eigenvalues are discrete representations of observables maintained by the successive cognitive operations of a cognitive agent. Notice that the representations and their stability are specific to the particular cognitive operations and how they recognize observables, that is, these discrete representations exist only in relation to the very same operators that define them. Any system, cognitive or biological, which is able to relate internally, self-organized, stable structures (eigenvalues) to constant aspects of its own interaction with an environment can be said to observe eigenbehavior. Such systems are defined as *organizationally closed* because their stable internal states can only defined in terms of the overall dynamic structure that supports them. Organizationally closed systems are also *informationally open* [Pask, 1992], since they have the ability to classify their constructed environment in what might be referred to as *emergent representation*.

1.1 Attractor behavior, self-organization, and constructivism

An eigenvalue of an organizationally closed system can be seen as an attractor of a self-organizing dynamical system. The global "cooperation" of the elements of a dynamical system which spontaneously emerges when an attractor state is reached is understood as self-organization [von Foerster, 1960; Haken, 1977; Prigogine, 1985; Forrest, 1991; Kauffman, 1993]. The attractor behavior of any dynamical system is dependent on the structural operations of the latter, e.g. the set of boolean functions in a boolean network. Speaking of an attractor makes sense only in relation to its dynamical system, likewise, the attractor landscape defines its corresponding dynamical system. Further, attractor values can be used to refer to observables accessible to the dynamical system in its environment and therefore perform relevant classifications in such environment (e.g. neural networks). Naturally, and this is the crux of the constructivist position in the theory of organizationally closed systems, not all possible distinctions in some environment can be "grasped" by the autonomous system: it can only classify those aspects of its environment/ sensory-motor/cognitive interaction which result in the maintenance of some internally stable state or attractor (eigenvalue). In other words, not everything "out there" is accessible; only those things that a particular physiology can construct with the stabilities of its own dynamics are. As with eigenvalues, attractors must be discrete even if used to refer to continuous observables.

1.2 Emergence and levels of description

There are three levels that need to be addressed when dealing with the notion of emergent representation. First, there is the material, dynamical, substrate, which will be the causal basis for all other levels that we may further distinguish. Secondly, we have the attractor behavior of this dynamics. Finally, we have the utilization of the set of attractors (eigenvalues) as referents for some aspects of the interaction of the dynamical system itself with its environment, that is, as tokens for eigenbehavior. This indirect, constructed, "referring" results from the structural coupling [Maturana and Varela, 1987] of the dynamical system with the environment, and can be understood as a semantic relation.

The level of eigenvalues is emergent to the dynamics because it cannot be explained solely by a description of the latter. Stability of dynamical states is not expressed in the language of the interactions between the components of a dynamical system. At this lower level, there is no distinction between a stable and an unstable state. For instance, the transition rules of Conway's *game of Life* cannot describe what "blinkers" and "gliders" are. Likewise, the level of eigenbehaviors, or the *function* of attractors as referring to some constructed reality, is emergent to the eigenvalues since the latter can only describe stabilities of the dynamics and not any "standing for" relation necessary for eigenbehavior (e.g. streams of gliders as information carriers in a universal computer built out of *Life* patterns [Poundstone, 1987]). No physical or formal description of the dynamical system and its attractors alone will completely explainthis functional dimension [see Rocha, 1994a, 1995b; Rosen, 1995; Pattee, 1995]. Hence, we need complementary descriptions of the several levels involved in such organizationally closed, emergent, systems [Pattee, 1978].

2 Embodiment and self-organization

Varela, Thompson, and Rosch [1991] have proposed an embodied, inclusive, approach to cognition which acknowledges the different levels of description necessary to effectively deal with emergent representation, or in von Foerster's terms, eigenbehavior. Cognitive science used to be traditionally concerned solely with those aspects of cognitive representation which can be described as symbolic. In other words, it was concerned with the semantic relation between cognitive categories and their environmental counterparts through some direct representational relation (intentionalty), without taking into account any sort of material or internal organizational constraints: real-world categories directly represented by discrete symbols which could be freely manipulated. The connectionist, emergent, or self- organizing paradigm has changed this focus to the lower level of attractor behavior. That is, cognitive systems are defined as those systems capable of self-organizing their components into discrete basins of attraction used to discriminate the environment they are able to construct. Classifications become subsymbolic and reside in some stable pattern of activation of the dynamic system's components, instead of based on some higher level symbols (emergent representation).

2.1 Selected Self-organization: structural change and increasing variety

What is usually referred to as self-organization is the spontaneous formation of well organized structures, patterns, or behaviors, from random initial conditions. The systems used to study this phenomenon are referred to as dynamical systems: state-determined systems. They possess a large number of elements or variables, and thus very large state spaces. However, when started with some initial conditions they tend to converge to small areas of this space (attractor basins) which can be interpreted as a form of self- organization. Since such formal dynamical systems are usually used to model real dynamical systems such as chemical networks of reactions, non-equilibrium thermodynamic behavior [Nicolis and Prigogine, 1977] the conclusion is that in nature, there is a tendency for spontaneous self-organization which is therefore universal [Kauffman, 1993].

This process of self-organization is also often interpreted as the evolution of order from a disordered start. Self-organizing approaches to life (biological or cognitive), in particular second-order cybernetics [see Pask, 1992], take chaotic attractors as the mechanism which will be able to increase the variety (physiological or conceptual) of organizationally closed systems. External random perturbations will lead to internal chaotic state changes; the richness of strange attractors is converted to a wide variety of discriminative power. Dynamic systems such as boolean networks clearly have the ability to discriminate inputs. Generally, the attractors of their dynamics are used to represent events in their environments: depending on inputs, the network will converge to different attractors. However, for any classification to have survival value, it must relate its own constructed states (attractors) to relevant events in its environment, thus, similar events in the world should correspond to the same attractor basin. Chaotic systems clearly do not have this property due to their sensitivity to initial conditions. Ordered systems follow this basic heuristic.

Kauffman [1993, page 232] further hypothesizes that "living systems exist in the [ordered] regime near the edge of chaos, and natural selection achieves and sustains such a poised state". This hypothesis is based on Packard's [1988] work showing that when natural selection algorithms are applied to dynamic systems, with the goal of achieving higher discriminative power, the parameters are changed generally tolead these systems into this transitional area between order and chaos. This idea is very intuitive, since chaotic dynamical systems are too sensitive to parameter changes, that is, a single mutation leads the system into another completely different behavior (sensitive to damage). By contrast, ordered systems are more resilient to damage, and a small parameter change will usually result in a small behavior change which is ideal for smooth adaptation (hill-climbing) in correlated fitness landscapes. However, even though very ordered systems can adapt by accumulation of useful successful variations (because damage does not propagate widely), they may not be able 'step out' of certain areas of their fitness landscapes. It is here that systems at the edge of chaos enter the scene; they are not as sensitive to damage as chaotic systems, but still they are more sensitive than fully ordered systems, and thus, some mutations will accumulate (by causing minor changes) and some others will cause major changes in the dynamics allowing more distant searches in fitness spaces. These characteristics of simultaneous mutation buffering (to small changes) and dramatic alteration of behavior (in response to larger changes) is ideal for evolvability [Conrad, 1983, 1990].

Chaotic classifications cannot grasp an ordered interaction with an environment, while point attractors and simple limit cycles may not allow enough behavior change for a good increase in variety. The edge of chaos regime seems to offer a good, intuitive, compromise. However, whatever the regime of a dynamic system, self-organization alone cannot escape its own attractor behavior. A given dynamic system is always bound to the complexity its attractor landscape allows. For a dynamic system to observe genuine emergence of new classifications (conceptual or of functionality) it must change its structure. Creativity, or open-ended variety can only be attained by structural perturbation of a dynamical system. One way or another, this structural change leading to efficient classification (not just random change), has only been achieved through some external influence on the self-organizing system. Artificial neural networks discriminate by changing the structure of their connections through an external learning procedure. Evolutionary strategies rely on internal random variation (mutation) which must ultimately be externally selected. In other words, the self-organizing system must be structurally coupled to some external system which acts on structural changes of the first and induces some form of explicit or implicit selection of its dynamic representations: *selected self-organization*.

2.2 Memory and selected self-organization

The dynamical approach of von Foerster [1965] to cognition emphasized the concept of memory without a record. By utilizing functionals to change the functions of state-determined systems, von Foerster formalized the idea that memory can be observed in systems which are able to change their own structure and therefore its dynamics and attractor behavior. Today, we name this kind of memory *distributed*, and the kind of models of memory so attained as connectionist. As previously discussed, for a self-organizing system to be informationally open, that is, for it to be able to classify its own interaction with an environment, it must be able to change its structure, and subsequently its attractor basins, explicitly or implicitly. Explicit control of its structure would amount to a choice of a particular dynamics for a certain task (the functional would be under direct control of the self-organizing system) and can be referred to as *learning*. Under implicit control, the self-organizing system is subjected to some variation of its structure (including its distributed memory) which may or may not be good enough to perform our task. Those self-organizing systems which are able to perform the task are thus *externally selected* by the environment to which they are structurally coupled. If reproduction is added to the list of tasks these systems can produce based on their dynamic memories, then we have the ingredients for natural selection: heritable variation and selection.

This form of situated, embodied, self-organization can be referred to as *distributed memory selected self- organization*. Its relying on some system-environment coupling of structure has been stressed mostnotably within second-order cybernetics and systems research. Maturana and Varela [1987] propose structural coupling as the general mechanism for variety increase, Pask [1976] refers to it as conversation in the cognitive realm. Both of these approaches owe a lot to von Foerster's eigenbehavior notions. More recently, in the realm of complex systems and evolutionary systems theory, Kauffman [1993] and others have relied on the notion of autocatalytic sets which are mutable, heritable, self-replicating, self- organizing systems evolvable through natural selection.

So far I have maintained that eigenvalues or attractors represent the building blocks of any system capable of discriminating its environment through some thus embodied construction. However, eigenbehavior (emergent representation) and its variety increase needs a structural coupling of these eigenvalues with some externally selective environment. This kind of selected self-organization obliges us "to understand perception not just as an interactive dynamical structure, but as a process that arises from a more fundamental embodiment that makes it possible for evolution to create structures that are internally assigned interactive roles. This process carries with it an increase of complexity of the way the environment is perceived and acted upon" [Etxeberria, 1995]. It also seems to offer a minimum requirement for evolution and cognitive categorization [Lakoff, 1987; Rocha, 1995d].

Perhaps the most important characteristic of this distributed memory selected self-organization is the fact that its specific embodiment both constructs the classification of the environment and ultimately defines selection. The consequence of this fact for biological systems is that natural selection (acting on this form of self-organization) is not free to evolve any organism, but it is constrained by the self-organizing properties of the materiality of the organisms it acts upon _ evolution with both a self-organizing and selection component. The consequence for cognitive systems, is that what can be classified is also constrained by the particular materiality of the classifying system at stake _ not everything "out there" can be grasped. In other words, the particular self-organizing dynamics of a particular classifying system constrains the universality of its classification. However, we should look into how can this process be made more efficient, and allow for genuine open-ended emergence of variety in classification.

3 Von Neumann: description based selected evolution

Von Neumann [1966] defended that a threshold of complexity exists, before which complexity degenerates, and after which complexity can increase in an open-ended fashion. He proposed a self-replicating scheme based on the notion of a memory-stored description $\Phi(A)$ that can be interpreted by auniversal constructor *A* to produce *A* itself. However, to avoid a logical paradox of self-reference, the description, which cannot describe itself, must be both copied (*uninterpreted* role) and translated (*interpreted* role) into the described automaton. This way, in addition to the universal constructor, an automaton *B* capable of copying any description, Φ, is included in the self-replication scheme. A third automaton *C* is also included to effect all the manipulation of descriptions necessary. To sum it up, the self-replicating system contains the set of automata ($A + B + C$) and a description $\Phi(A + B + C)$; the description is fed to *B* which copies it and to *A* which constructs another automaton ($A + B + C$); the copy is then handled separately to the new automaton which together with this description is also able to self- reproduce.

3.1 Descriptions and open-ended evolution

As Von Neumann [1966] discussed, if the description of the self-reproducing automata is changed (mutated), in a way as to not affect the basic functioning of ($A + B + C$) then, the new automaton ($A + B + C$)' will be slightly different from its parent. Von Neumann used a new automaton *D* to be included in the self-replicating organism, whose function does not disturb the basic performance of ($A + B + C$); ifthere is a mutation in the *D* part of the description, say D', then the system $(A + B + C + D) + \Phi(A + B + C + D')$ will produce $(A + B + C + D') + \Phi(A + B + C + D')$. Von Neumann [1966, page 86] further proposed that non-trivial self-reproduction should include this "ability to undergo inheritable mutations as well as the ability to make another organism like the original", to distinguish it from "naive" self- reproduction like growing crystals. Von Neumann's model clearly does not rely on a distributed but on a local kind of memory. Descriptions entail a symbol system on which construction commands are cast. These commands are not distributed over patterns of activation of the components of a dynamic system, but instead localized on "inert" structures which can be used at any time _ a sort of random access memory. By "inert" I mean material structures with many dynamically equivalent states, in other words, the semantic relation, or what the structures are used to refer to, must possess a large degree of arbitrariness so that certain representations are not much more probable than others. In the genetic system, any sequence of nucleotides is possible, and its informational value is not dependent on the particular attractor behavior of DNA or RNA dynamics.

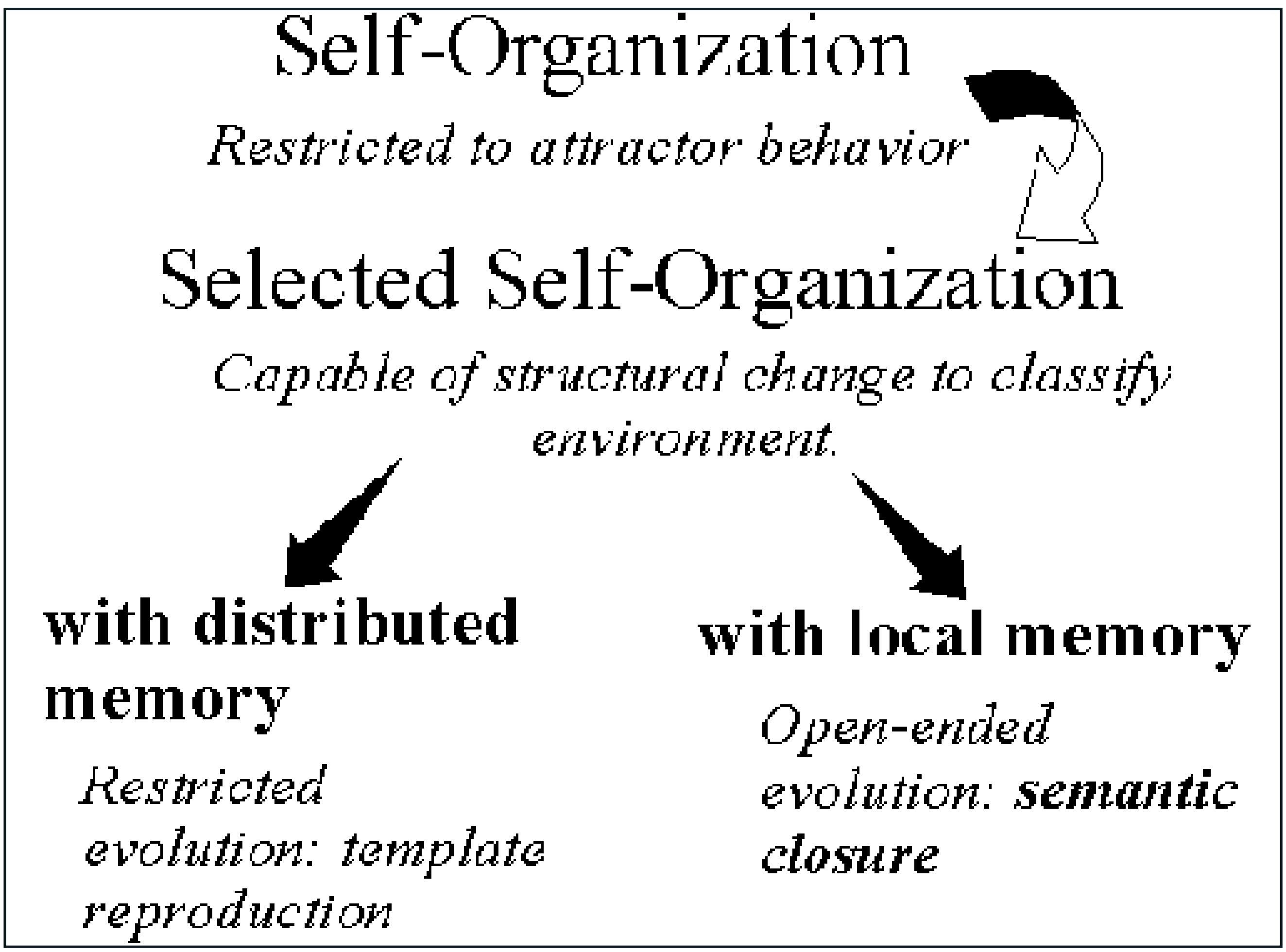
Why then is there an advantage of local memory over distributed memory self-replication? Von Neumann's argument mainatins that if we do not have symbolic descriptions directing self-replication, then an organism must replicate through material self-inspection of its parts. In other words, the dynamics must be able to produce copies of itself by template identification of parts existing in its environment. The simplest way would be to have every part of the structure individually heritable. Clearly, as systems grow in complexity, self-inspection becomes more and more difficult [Pattee, 1995]. The existence of a language, a symbol system, allows a much more sophisticated form of communication. Functional, dynamic structures do not need to replicate themselves, they are simply constructed from physically non- functional (dynamically inert) descriptions. For instance, for an enzyme to replicate itself, it would need to have this intrinsic property of self-replication "by default", or it would have to be able to assemble itself from a pool of existing parts, but for this, it would have to "unfold" so that its internal parts could be reconstituted for the copy to be produced [Pattee, 1995]. With the genetic code, however, none of these complicated "gimmicks" are necessary: functional molecules can be simply folded from inert messages. This method is by far more general since any functional molecule (with limitations to be discussed ahead) can be produced from a description, not merely those that either happen to be able to self-reproduce, or those that can unfold and fold at will to be reproduced from available parts. The evolution of distributed memory based self-organizing systems is restricted to this type of trivial (in von Neumann's sense) or through self-inspection (self-description [Kampis, 1991]) reproduction.

The symbol system, with its utilization of inert structures, opens up a whole new universe of functionality which is not available for purely dynamical self-replication. In this sense, it can evolve functions in an open-ended fashion. The threshold of complexity proposed by Von Neumann is taken by some (e.g. Pattee, Cariani, Kampis in Rocha [1995a]) as another category of self-organization which is capable of creative organization and selection from outside. Following our rationale above, we can call it *local memory selected self-organization*, or *description based selected self-organization*. In biology, this means that living systems can follow a largely open-ended evolutionary history (von Neumann;s threshold of complexity). In the cognitive realm, the introduction of symbols also opened up a whole new world of communication possibilities as the aspects of an environment that can be communicated between individuals is not restricted to only those things we can "show" or otherwise somehow physically mimic: the displacement of local observations.

3.2 Semantic Closure: open-endedness, materiality, and universality

The notion of description implies a self-referential linguistic mechanism. A description must be cast on some symbol system while it must also be implemented on some physical structure. Since manyrealizations of the same symbol system are possible, viewing descriptions only as physical systems explains nothing about their symbolic nature in the control of construction. When *A* interprets a description to construct some automaton, a *semantic* code is utilized to map instructions into physical actions to be performed. When *B* copies a description, only its *syntactic* aspects are replicated. Now, the language of this semantic code presupposes a set of material primitives (e.g. parts and processes) for which the instructions are said to "stand for". In other words, descriptions are not universal as they refer to some material constituents which cannot be changed without altering the significance of the descriptions. We can see that a self-reproducing organism following this scheme is an entanglement of symbolic controls and material constraints which is closed on its semantics. Howard Pattee [1982, 1995] calls such a principle of self-organization *semantic closure*.

It is important to understand that when we say that a description based selected self-organizing system is endowed with open-ended evolutionary potential we do not believe it is universal, that is, that any physical system can be evolved. A given semantically closed system is based on some sort of coding mechanism between inert and functional structures. However, the code and the associated construction are built on some material substrate constraining the whole semantic closure: there is a finite number of functional structures which may be constructed with a given set of parts. The degree of open-endedness will be dependent on the representational potential of this code. In other words, the larger the number of possible equally dynamically inert structures, the larger the universe of functionality that can be represented in them. For instance, living systems cannot evolve any functional structure whatsoever (we have never seen animals on wheels for instance), but still the number of possible functional combinations attainable with the DNA-protein code system is very large, far beyond computational limits. In this sense, the emergence of functionality is open-ended [Cariani, 1989, 1993] though not universal.



It is here that the emphasis on the symbolic level of open-ended evolutionary systems must be tamed. Strong Darwinism, has emphasized the nature of the symbolic description of living systems, as much as strong cognitivism has emphasized the symbolic nature of cognition. However, semantic closure with its description based selected self-organization is not reiterating this position. The symbolic component of open-ended evolutionary systems is stressed, but the material, dynamic, self-organizing characteristics of matter are equally stressed. It is the ultimate inclusive approach which is neither reductionist nor dualist [Pattee, 1995]. While it is maintained that a purely physical description or dynamics will not explain symbolic function (as several material systems may implement the same function), it is also maintained that different material structures will not have identical domains of potentially evolvable functions. The important idea is that evolution relies both on self-organization and selection, and only those self- organizing systems able to harness their dynamics to obtain a symbolic dimension can have open-ended evolutionary potential.

4 Evolving semiotics: a conceptual framework for inclusive self-organization

Semiotics concerns the study of signs/symbols in three basic dimensions: syntactics (rule-basedoperations between signs within the sign system), semantics (relationship between signs and the world external to the sign system), and pragmatics (evaluation of the sign system regarding the goals of their users) [Morris, 1946]. The importance of this triadic relationship in any sign system has been repeatedly stressed by many in the context of biology and genetics [e.g. Waddington, 1972; Pattee, 1982, 1995]; in particular, Peter Cariani [1995] has presented an excellent discussion of the subject. We can understand the semiotics of the genetic system if we consider all processes taking place before translation (from transcription to RNA editing) as the set of syntactic operations; the relation between mRNA (signifier) and folded amino acid chains (signified), through the genetic code, as the implementation of a semantic relation; and finally, the selective pressures on the obtained proteins as the pragmatic evaluation of the genetic sign system.

4.1 Semiotics with two symbol types

Until now, the semiotics of DNA has been considered strictly unidirectional: DNA stands for proteins to be constructed. In other words, the symbolic DNA encodes (through the genetic code) actions to be performed on some environment. Naturally, through variation and natural selection (pragmatic evaluations) new semantic relations are created which are better adapted to a particular environment, however, real-time contextual measurements are not allowed by this unidirectional semiotics. If in addition to symbols standing for actions to be performed, the genetic system is also allowed a second type of symbols standing for contextual, environmental, measurements, then a richer semiotics can be created which may have selective advantage in rapidly changing environments, or in complicated, context dependent, developmental processes. Figure 2 depicts such a sign system. The top plane contains two different types of symbols which are combined in different ways (symbolic operations). *Type 1* symbols stand for actions through a *code* ϕ (e.g. the genetic code) and *type 2* symbols stand for measurements through a different *code* γ which is being hypothesized here. In Rocha [1995c] evidence was presented to show that RNA editing may be seen as a mechanism for this contextual input, at least for certain well known living organisms like the african trypanosomes [Benne, 1993], and as a potentially important mechanism in the morphogenesis of highly evolved animals [Lomeli et al, 1994]. We can think of DNA as a set of symbolic descriptions based on two types of symbols: *type 1* symbols are expressed in mRNA molecules and stand for actions to be performed; *type 2* symbols are expressed in some sort editing mechanisms (e.g. gRNA molecules in the genetic system of the african trypanosomes) which stand for contextual observables. RNA editing can be seen as a set of symbolic operations performed with symbols of both types, resulting in symbols of *type 1* to be translated into actions by the genetic code.

Notice that *code* γ is proposed here as an abstraction referring to the set of mechanisms which will link environmental measurements (context) into *type 2* symbols. It is **not** expected to function as a proper genetic code. Jon Umerez [1995] has stressed the importance of a code in any form of evolving semiotics. In simple terms, what I refer to as a code here is any mechanism able to relate "inert" material structures to other material structures with some functional dynamics "by virtue" of a larger organizational closure. In other words, thefunction of the first material structures is not dependent on its particular materiality, but on what they are used to refer to for the imbedding, material, self-referent semantic closure [Pattee, 1995]. Again, a semantically closed system, endowed with this kind of symbol/matter code is able establish open-ended evolution [Pattee, 1995; Umerez, 1995]. Leaving pragmatic evaluations (selection) out of the picture momentarily, the semantic closure with two symbol types, which is able to act as well as perform measurements on its environment can be represented by the cube in figure 3. The semiotic triadic relationship is only complete when individual semantic closures are coupled to an environment (measured and acted upon by each one of them) which ultimately selects (pragmatic evaluation) the most fit amongst these symbol-matter closures (e.g. in natural selection, those that reproduce the most).

4.2 Materiality and implementation dependence: self-organization and selection come together

The issue of materiality is extremely important for two reasons: (i) all which can be represented in this evolutionary semiotics is restricted to what can be constructed by the specific, material, semantically closed system in the first place; and (ii) selection is ultimately performed on this specific material organization capable of performing a number of functions in an environment. The conceptual framework put forward by this material, evolutionary, semiotics forces self-organization and selection together as two indispensable dimensions of evolutionary systems. Pragmatic evaluations or selection takes place on particular dynamics, on the other hand, open-ended evolution is only possible through the existence of a symbolic dimension mediated through a code. Moreover, this code must be built out of some materiality which constrains its representation power and which also ultimately defines eigenbehavior, or an organism's ability to construct and discriminate its environment. This last point raises the issue of implementation-independence and multiple realizability [Umerez, 1995].

A semantically closed system is not implementation independent because matter constrains its eigenbehavior as well as its evolutionary potential. The second constraint is clear when we realize that two distinct closures which at some point establish the same eigenbehavior (the same representational function), if materially different, will evolve differently. The first constraint is not so clear since we hypothetically allow the idea that two different closures can have the same representational function. However, this equivalence can only be established between formal symbol systems which by definition are not materially constrained and are therefore universal, that is, the set of possible semantic relations is infinite (figure 4). Material symbol systems do not have this property. A coding relation must be formed out of certain available material parts in each domain (e.g. nucleotides and aminoacids in the genetic code), and no semantic relation can escape them. In the genetic system we can represent any protein, but we cannot represent and construct any other material structure which is not made out of aminoacid chains. Thus, our semiotics are necessarily constrained by matter, not just due to selection pressures, but on account of the parts available for the symbol system itself (figure 5).

Material sign systems are not universal and cannot represent anything whatsoever, but this turns out to be their greatest advantage. The price to pay for the universality of formal symbol systems is complete specificity, that is, full description of its components and behavior. Conversely, material sign systems are built over certain building blocks which do not need a description. For instance, DNA does not need toencode anything but aminoacid chains, there is no need to include in genetic descriptions information regarding the chemical constituents of aminoacids nor instructions on how to fold an aminoacid chain -- folding comes naturally from the dynamical self-organization of aminoacid chains. Notice how a logical simulation of these genetic mechanisms needs to include all this information that comes free when the self-organizing characteristics of matter are actually used rather than simulated [Moreno et al, 1994].

5 What does it mean for applications?

5.1 Evolutionary strategies: selection alone

The underlying idea of computational evolutionary strategies (ES) is the separation of solutions for a particular problem (e.g. a machine) from *descriptions* of those solutions through a code. Genetic algorithms (GA's) work on these descriptions and not on the solutions themselves, that is, variation is applied to descriptions, while the respective solutions are evaluated, and the whole (description-solution) selected according to this evaluation. This separation follows von Neumann's self-reproducing scheme which is able to increase the complexity of the machines described. This leads to the conclusion that the form of organization attained by GA's is not self-organizing in the sense of a boolean network or cellular automata. Even though the solutions are obtained from the interaction of a population of elements, and in this sense following the general rules usually observed by computationally emergent systems, they do not strictly ***self***-organize since they rely on the selective pressures of some fitness function. The order so attained is not solely a result of the internal dynamics of a collection of interacting elements, but also dictated by the *external* selection criteria. To say that the populations of descriptions of solutions self- organize *at all* in ES may stretch the concept of self-organization a bit too far. ES rely on different concepts: first, with the description-solution dichotomy the concept of local memory is introduced; second, the transition rules of ES are not state-determined _ variation is stochastic; third, as already discussed, selection is external to the populations of descriptions. This way, we can hardly say that a population of memories is interacting with any sort of *"self-dynamics":* the solutions reached by a GA do not self-organize but are a result of external variation and selection. For all these reasons, it is therefore natural to think of ES as completely distinct from self-organization. It is perhaps useful to think of ES as modeling a very different aspect of biological systems that has to do with natural selection. Self- organizing systems model the abstract, internal, characteristics of matter, while ES model the existence of, external, selective pressures on populations of varying memory based descriptions of some system.

5.2 Artificial semantic relations: the origin problem

The coded relationship between descriptions and solutions for some task in ES is imposed at the onset by the users of such systems. Likewise, the database symbols of some artificial intelligence program are externally related to some categories its users are interested in. Both have to do with the issue of representation in computational domains. All formal systems must have their symbols related to some meaning by the external intervention of some user [Rocha, 1995b], in other words, a formal system cannot change the signifier/signified primitives imposed when it is started, and create new observables [Cariani, 1991]. In the field of GA's some [Mitchell and Forrest, 1994] have been calling for more research to be done on schemes that may allow the evolution of the description/solution relationship itself, that is, the evolution of a code. The same quest takes place in cognitive science for some way to ground the symbols of artificial intelligence models [Harnad, 1990].

Basically, everyone is one way or another dealing with the origin of symbols problem, or in other words, the matter/symbol problem. Some explain symbols away by searching explanations in the dynamics of cognitive and biological systems [e.g. Churchland and Sejnowski, 1991] while others, usually in strong computationalist fields, will look solely at the purely symbolic aspects of complicated systems. Few havebeen calling for the inclusion of both aspects into complementary approaches [Pattee, 1978; Lakoff, 1987; Cariani, 1987; Varela, Thompson, and Rosch, 1991; Etxeberria, 1995]. This latter view calls for an embodiment of models of life and cognitionin such a way as to be able to study the origin problems within an inclusive framework where material and computational aspects are intertwined.

In any case, however far we may be from solving any problems of origin, we may still recognize that both life and cognition rely on complementary dynamical and symbolic characteristics. Even if we do not yet know how these aspects ever came to be brought together, we should build artificial models using both of these aspects (or their simulations) to our advantage, since they have proved to be immensely powerful for natural organisms. For instance, in [Rocha, 1995c], even though using a fixed computational coding relations between descriptions and solutions in a

GA, I proposed the establishment of, stochastic, contextual constraints on this coding relation following the basic mechanisms of RNA editing found in a variety of living organisms. These contextual GA's, though completely computational, are able to change the way they produce solutions from the same genetic description, according to changes in their environments. They are an instance of the two symbol type semiotic model discussed in section 3, and can be said to evolve an internal control of genetic expression which may be of use for organisms whose environment is subjected to cyclic changes.

5.3 Genetic algorithms and development: self-organization and selection in Artificial Life

Lately much attention has been posited on evolutionary strategies that bring together self-organizing systems and natural selection inspired algorithms. Particularly in the field of Artificial Life, Kitano[1994], and Dellart and Beer [1994], have proposed GA's which do not encode directly their solutions, but rather encode generic rules (through L-Systems) which develop into boolean networks simulating given metabolic cycles. With these approaches, GA's no longer model exclusively selection, but also a self- organizing dimension standing for some materiality. The GA does not search the very large space possible solutions, but a space of basic rules which can be manipulated to build different self-organizing networks. These networks are then started (sometimes with some learning algorithm) and will converge to some attractor behavior standing for a solution of our simulation. Rather than directly encoding solutions, the GA harnesses a space of possible self-organizing networks which will themselves converge to a solution -- *emergent morphology*.

The computational advantage of these systems lies on the tremendous reduction of the algorithm's search space since the solutions do not have to be encoded in all details, the emergent morphology "takes care" of details we do not need to encode. In particular, I have proposed a developmental scheme [Rocha, 1995c] which uses the same search space (based on fuzzy rules) for whatever number of simulation primitives we desire, in other words, a generic GA which uses the same state space regardless of the simulation task by utilizing an emergent morphology scheme based on fuzzy logic. By simulating both selection and self-organization, the size of descriptions is dramatically reduced, and an avenue is opened for studying the simulation of both the symbolic and material aspects of evolutionary systems.

5.4 Categorization and constructivism: uncertainty and belief in artificial intelligence

Eleanor Rosch [1978] and George Lakoff [1987], among others, have stressed the importance of an embodiment of cognition to deal with its representation issues. In Rocha [1994b, 1995d, 1995e] I have introduced a set structure called evidence set based on fuzzy logic and the Dempster-Shafer [Shafer, 1976] theory of evidence. These structures allow the inclusion of all forms of uncertainty recognized in information theory [Klir, 1993] as well as a formalization of belief and contextual dependencies in a set format. Evidence sets do not specifically include an account of materiality, however, the formalization of belief and context allows larger imbedding models of cognitive categorization to base the belief andcontextual strengths of concept membership on specific material constraints, or its simulation through, say, neural networks.

The contextual pointers of evidence sets are related to Pask's [1976] P-individuals in his conversation theory and are thus embedded in a constructivist framework which emphasizes the construction of a reality in terms of a cognitive system's specific materiality and environmental coupling. This is also a direct result of von Foerster's formulation of eigenbehavior and an aid to establishing another instance of the semiotic model of section 3 in the cognitive realm. It can be seen to offer a constructivist position of representation which stresses embodiment, but must also, on the other hand, concede that in an evolutionary context, the construction of categories must have a representational relation to aspects of the organism's environment, or its categorization would not have survival value in that particular organism/environment structural coupling [Medina-Martins and Rocha, 1992; Rocha, 1995d]. In other words, embodiment does not eradicate the necessity to still explain some sort of representational relation between constructed categories and the cognitive system's context.

6 Conclusions: selection meets self-organization

I have stressed that though self-organizing systems with distributed memory represent a minimum requirement for evolutionary systems, their evolutionary potential is much larger, possibly open-ended, if further endowed with dynamically "inert" structures to be used by their classification mechanisms. It was stressed that this by no means entails a return to purely symbolic approaches to cognition, nor a belief in the absolute sovereignty of natural selection in evolution. Rather, it is a call for more inclusive, hybrid approaches to such evolutionary and learning systems. In artificial Life this implies building models which bring together self-organizing mechanisms, such as cellular automata or boolean networks, with genetic algorithms (with varying degrees of control of their genetic expression). In Artificial Intelligence it implies the establishment of models able to go beyond connectionist classification, by inclusion of higher level accounts of cognitive categorization.

7 References

Benne, Rob (Ed.) [1993]. *RNA Editing: The Alteration of Protein Coding Sequences of RNA*. Ellis Horwood.

Cariani, Peter [1991]."Some Epistemological Implications of Devices which Construct their own Sensors and Effectors." In: *Towards a Practice of Autonomous Systems.* Varela and Bourgine (Eds.). MIT pp 484-493.

Cariani, Peter [1995]."Towards an evolutionary semiotics: the role of symbols in organisms and adaptive devices." In: *Proc. of the ISES Vienna 1995*. Stanley Salthe and Gertrudis Van de Vijver (eds). In Press.

Churchland, Patricia S. and T.J. Sejnowski [1992]. *The Computational Brain.* MIT Press.

Conrad, Michael [1983]. *Adaptability*. Plenum Press.

Conrad, Michael [1990]."The geometry of evolutions." In: *BioSystems* Vol. 24, pp. 61-81.

Dellaert, F. and R.D. Beer [1994]."Toward an evolvable model of development for autonomous agent synthesis." In: *Artificial Life IV*. R. Brooks and P. Maes (Eds.). MIT Press.

Etxeberria, Arantza [1995]."Embodiment of Natural and Artificial Systems." In: *Proceedings of the International Seminar on Evolutionary Systems, Vienna 1995*. G. van de Vijver and S. Salthe (Eds.). In Press.

Haken, H. [1977]. *Synergetics.* Springer-Verlag.

Harnad, Stevan [1990]."The symbol grounding problem." In: *Emergent Computation*. S. Forrest (Ed.). MIT Press.

Kampis, George [1991]. *Self-Modifying Systems in Biology and Cognitive Science. .*

Kauffman, S. [1993]. *The Origins of Order: Self-Organization and Selection in Evolution.* Oxford University Press.

Kitano, Hiroaki [1994]."Evolution of Metabolism for Morphogenesis." In: *Artificial Life IV*. Brooks, R.A. and P. Maes. MIT Press. pp 49-58..

Klir, George J. [1991]. *Facets of Systems Science.* Plenum Press.

Klir, George J. [1993]."Developments in uncertainty-based information." In: *Advances in Computers*. M. Yovits (Ed.). Vol. 36, pp 255-332.

Lakoff, G. [1987] *Women, Fire, and Dangerous Things*. Chicago University Press.

Maturana, H., and F. Varela [1987]. *The Tree of Knowledge.* New Science Library.

Medina-Martins, Pedro R. and Luis Rocha [1992]."The in and the out: an evolutionary approach." In: *Cybernetics and Systems Research '92*. Robert Trappl. World Scientific Press. pp 681-689.

Mitchell, M. and S. Forrest [1994]."Genetic algorithms and Artificial Life." In: *Artificial Life* Vol. 1, pp 267-289.

Moreno, A., A. Etxeberria, and J. Umerez [1994]."Universality without matter?." In: *Artificial Life IV*. R. Brooks and P. Maes (Eds). MIT Press, pp.406-410.

Morris, Charles W. [1946]. *Signs, Language, and Behavior.* G. Braziller, New York.

Nicolis, G. and I. Prigogine [1977]. *Self-Organization in Nonequilibrium Systems*

Packard, N. [1988] "Adaptation to the edge of chaos". In: *Complexity in Biologic Modelling*. Kelso and Shlesinger

Pask, Gordon [1976]. *Conversation Theory: Applications in Education and Epistemology*. Elsevier.

Pask, Gordon [1992]."Different kinds of Cybernetics." In: *New Perspectives on Cybernetics*. Gertrudis Van de Vijver (Ed.). Kluwer Academic Publishers. pp. 11-31.

Pattee, Howard H. [1978]."The complementarity principle in biological and social structures." In: *Journal of Social and Biological Structures* Vol. 1, pp. 191-200.

Pattee, Howard H. [1982]."Cell psychology: an evolutionary approach to the symbol-matter problem." In: *Cognition and Brain Theory* Vol. 5, no. 4, pp 325-341.

Pattee, Howard H. [1995]."Evolving self-seference: matter, symbols, and semantic closure." *Communication and Cognition - AI* Vol. 12, nos 1-2 (Rocha [1995a]). pp. 9-27 .

Prigogine, I. [1985]."New perspectives on complexity." In: *The Science and Praxis of Complexity*. United Nations Library. Reprinted in Klir [1991], pp. 483-492.

Rocha, Luis M. [1994a]."Von Foerster's cognitive tiles: semantically closed building blocks for AI and Alife." In: *Cybernetics and Systems ' 94*. Robert Trappl (Ed.). Vol. 1, pp 621-628. World Scientific Press.

Rocha, Luis M. [1994b]."Cognitive Categorization revisited: extending interval valued fuzzy sets as simulation tools for concept combination." In: *Proc. of the 1994 Int. Conf. of NAFIPS/IFIS/NASA*. IEEE. pp 400-404.

Rocha, Luis M. (Ed.) [1995a]. *special issue in Self-Reference in Biological and Cognitive Systems. Communication and Cognition - Artificial Intelligence* Vol. 12, nos. 1-2

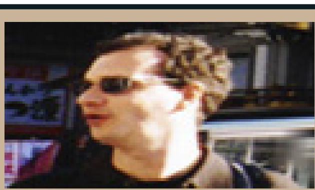
Rocha, Luis M. [1995b]."Artificial semantically closed objects." *Communication and Cognition - AI* Vol. 12, nos. 1- 2 (Rocha[1995a]). pp. 63-90.

Rocha, Luis M. [1995c]."Contextual Genetic Algorithms: Evolving Developmental Rules." In: *Advances in Artificial Life*. F. Moran, A. Moreno, J.J. Merelo, and P. Chacon (Eds.). Springer-Verlag. pp. 368-382.

Rocha, Luis M. [1995d]."(Interval based) Evidence Sets: Modelling Subjective Categories." In: *International Journal of General Systems* In Press.

Rocha, Luis M. [1995e]."Computing Uncertainty in Interval Based Sets." In: *Applications of Interval Computation*. R.B. Kearfott and V. Kreinovich (Eds.). Kluwer. (In Press).

Rosch, E. [1978]."Principles of Categorization." *Cognition and Categorization*. Rosch and Lloyd (Eds.). Hillsdale.



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Online self-organizing social systems:

The decentralized future of online learning

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Online self-organizing social systems: The decentralized future of online learning

Introduction

The development of innovative network applications marches on at an astounding rate. Ten years ago who could have predicted the impact of the World Wide Web? Who could have predicted the impact of Napster just two years ago? And who knows what will be next? Such is the conundrum of the instructional technologist who struggles to employ ever-emerging technologies in the service of learning.

But not all advances in instructional technology come about through the development of new hardware or software – some emerge from the *creative applications of existing technology*. In this article we discuss such an innovation, the online self-organizing social system (OSOSS). Briefly described, the OSOSS structure allows large numbers of individuals to self-organize in a highly decentralized manner in order to solve problems and accomplish other goals. The OSOSS structure is neither an instructional design theory (such as those described by Reigeluth, 1999) nor an application or Internet protocol (such as Netscape or HTTP). However, due to its distributed and highly decentralized nature, the authors feel that the OSOSS structure could prove as disruptive to traditional notions of online learning as Napster proved to traditional conceptions of the Internet.

Our discussion of self-organizing social systems online will begin with an exploration of the issue of scalability and bandwidth in online learning, and the means currently proposed for overcoming these issues: "learning objects" automatically assembled by intelligent instructional systems. We will discuss what we feel are weaknesses in the automated learning objects approach. Finally, we will use these explorations and discussions as a context for describing the OSOSS structure.

Issues of scalability and bandwidth in online learning

When bandwidth issues are discussed in the context of online learning, one frequently thinks of the speed with which a large amount of data can make its way to students' homes. In the past five years broadband deployment has increased significantly, and it is possible that eventually there may be high speed Internet access generally available in student homes.

Let us assume momentarily that this access is broadly available. Are the problems of online learning solved? No. We believe that the most significant bandwidth problem in online learning has nothing to do with pushing data through pipes. The idea of "teacher bandwidth" analogizes students to data, and teachers to pipes, and formulates the problem thus: how many students can a teacher support in an online learning environment? While some distance education organizations see the Internet as an opportunity to expand their student base to hundreds of thousands of students, providing feedback and learning support for such large numbers is problematic. Traditional instructional methods were designed to support tens of students in a course, not tens of thousands. When these "tried and true" instructional methods are moved intact online and the number of students increases by one thousand, the number of "teachers" required to personalize the learning experience must also increase. As the following quote from the Sharable Content Object Reference Model produced by the U.S. Department of Defense's Advanced Distributed Learning Network (ADL, 2001) points out, increasing the number of teachers proportionately is an expensive proposition:

> Empirical studies have raised national interest in employing education and training technologies that are based on the increasing power, accessibility and affordability of computer and networking technologies. These studies suggest that realizing the promise of improved learning efficiency through the use of instructional technologies—such as computer-based instruction, interactive multimedia instruction and intelligent tutoring systems—depends on the ability of those technologies to tailor instruction to the needs of individuals. In contrast to classroom learning, these approaches enable the pace, sequence, content and method of instruction to better fit each student's learning style, objectives and goals…
>
> The dilemma presented by individually tailored instruction is that it combines an instructional imperative with an economic impossibility. With few exceptions, one instructor for every student, despite its advantages, is not affordable. Instructional technology promises to provide most of the advantages of individualized instruction at affordable cost while maintaining consistent, measurable, high-quality content (p. 17-18).

The ADL quote summarizes many approaches to solving the scalability or "teacher bandwidth" problem:

1. A one-on-one instructional model in which a teacher tailors instruction to individual student needs is preferable to other instructional models,
2. Human (teacher-student) interaction in large scale learning environments is not economically feasible, therefore
3. Automating feedback and other learning support via intelligent instructional systems is the only viable solution to providing scalable online learning.

How does an organization scale to provide individualized learning support to large numbers of students? The solution that is becoming increasingly popular replaces human teachers with intelligent, automated systems. These systems sequence instructional modules or "learning objects" (Wiley, 2002) for users in real time according to intelligent algorithms, and provide predefined or "intelligent" feedback based on assessments of learners.

While a significant amount of energy and financing has gone into the automated learning objects approach to overcoming the teacher bandwidth problem, it suffers from a number of critical weaknesses.

1. Automated instructional systems completely lack human interaction and social negotiation, which learning theorists are increasingly stressing as crucial to supporting meaningful learning (Edwards & Wiley, 2002).
2. Highly decontextualized learning objects are reusable in the greatest number of learning contexts, but they are also the most expensive and difficult for instructional designers to reuse, creating a "reusability paradox" (Wiley, Recker, & Gibbons, 2001).
3. Computers are currently incapable of participating in the *very* human meaning-making activities required of instructional design and development based on fine-grained components (Edwards & Wiley, 2002).

While the automated systems approach has its place, we believe that these and other weaknesses prevent the method from supporting scalable solutions to human-interaction intensive learning. However, we are not advocating a return to the "one teacher for every student. The dualism of "teacher-supports-students" or "automated-system-supports-students" is a false dichotomy. There is another option – "students-support-each-other."

<u>The phenomenon of self-organization</u>

It may seem highly unlikely that any uncoordinated group of students could come together without a guiding authority to accomplish any significant purpose. Looking in on thousands of students using technology without a teacher's direction, one might ask with Maeterlinck (1927), "What is it that governs here? What is it that issues orders, foresees the future, elaborates plans, and preserves equilibrium?" The subject of Maeterlinck's wonder was not people, however – it was the white ant. Many species of ants, bees, termites and other social insects forage for resources, store resources, provide needed resources to others at the proper place and time, discriminate between optimal sources of food, build nests, hives, or domes, and solve a variety of other complex geometric, economic, and engineering problems.

Self-organizational models have been applied to human communities for decades, at least since Jacobs' (1961) groundbreaking work on urban planning. Jacobs argues that communities self-organize in a manner similar to social insects: instead of thousands of ants crossing each other's pheromone trails and changing their behavior accordingly, thousands of humans pass each other on the sidewalk and change their behavior accordingly. In the days before central planning authorities zoned city areas for specific uses, the simple local interactions of people on sidewalks led to complex global behavior at the level of the city, with upscale neighborhoods, slums, commercial and red light districts all emerging without anyone directing them to do so.

Researchers have continued to fruitfully apply self-organizational models to other human systems such as economics (Krugman, 1996). More recently, Eriksson and Wulf (1999) have begun exploring the relationships between self-organizing systems and the notion of computer-supported collaborative work; Wulf (1999) has examined the ways in which "groupware" systems support self-organization.

Current research brings us to the point where the self-organizational potential of human social systems has been recognized and documented, and investigations are beginning into the ability of networked technology to facilitate this self-organizing activity for individuals who are geographically distributed. Next, we will present a necessarily brief discussion of an existing online self-organizing social system.

Online self-organizing social systems

Online self-organizing social systems (OSOSS) are facilitated by a particular type of software infrastructure, one that is generally web-based and characterized by a high degree of management decentralization. (Similar structures can exist within other technological environments such as mailing lists or Usenet newsgroups, but these frequently have web-enabled front ends.) The website genre known as the “web log” or “blog” is such an infrastructure, and provides a fertile primordial soup from which online self-organizing social systems can emerge. The day-to-day tasks of creating new content, adding commentary, evaluating the quality of submitted material, providing user support and answering questions, and other tasks are distributed across the entire community via the blog infrastructure.

OSOSS vary in the degree of decentralization they employ (from very limited centralized editorial control to absolutely no central control), the content domain they cover (from the very specific to the self-proclaimed “Everything”), and the explicitness of their learning facilitation (from news OSOSS that help people keep up with current events to OSOSS explicitly created for the purpose of facilitating collaborative online problem solving). While none of the existing OSOSS consider themselves *learning* communities, learning *is* happening among their users, and happening in an extremely innovative manner.

Slashdot (http://slashdot.org/) is undeniably one of the most popular OSOSS. With a subscriber base of over 30,000 generating over 1,000,000 page impressions per day (OSDN, 2001), one might expect that the task of managing such a site would require scores of people. And it does. It takes approximately 30,000 people to keep Slashdot running, via an infrastructure supporting story submissions, threaded discussion, moderation, and meta-moderation.

Slashdot is a news site, carrying stories of interest to “geeks” and “nerds.” Frequent topics include bleeding edge hardware and software developments, intellectual property law and lawsuits, Japanese anime, and reviews of science fiction books and movies. Users contribute “news stories” – which are frequently summaries of stories, reviews, and other information found on other sites across the web, along with links to the original content – for the editors to approve. Editors review the material for appropriateness (alignment with Slashdot’s content areas) and originality (is this story already running on the front page?) and then either approve or discard the submission. Accepted submissions run in a box on the site’s front page (see Figure 1), and each story box contains a link to an area where threaded discussion dedicated to the story occurs (see Figure 2).

Figure 1. A screen capture of the Slashdot website located online at http://slashdot.org/

The threaded discussion itself is equally interesting. Community members meeting certain criteria have the ability to "moderate" or evaluate the quality of individual comments. These evaluations are aggregated to produce scores from –1 ("Flamebait") to 5 ("Insightful"). Using these comment ratings and an infrastructure that dynamically generates HTML, Slashdot allows users to set thresholds for the quality of comments to which they want to be exposed. Generally speaking, the authors have found that using the website with this threshold set at 4 or higher is an intellectually satisfying experience (see Figure 2).

"Meta-moderation" allow other members of the community to evaluate the appropriateness of moderators' ratings. For example, if a moderator with an axe to grind against Microsoft moderated an informative comment regarding the XP operating system down to –1, meta-moderators would mark this moderation as "Unfair." This system of meta-moderation provides the larger community a powerful balance against "the tyranny of the moderators."

The combination of Slashdot's moderation system with its meta-moderation system creates a powerful infrastructure for *real-time peer review*. This infrastructure supports the community's efforts to bring the best information, questions, and answers to the attention of the community, while making it difficult for misinformation and half-baked ideas to propagate across the network. In short, it functions much like the peer review process that provides the gateway to academic journals. It impressively fills this role a) in real-time, b) with input from a larger proportion of the community, and c) with meta-moderation checks in place to prevent abuse.

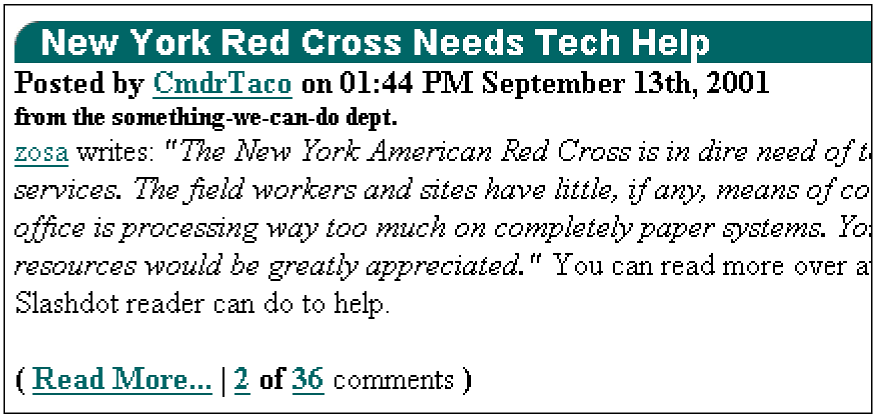

Figure 2. Detail of the Slashdot website front page. The "Read More" link takes users to a threaded discussion specific to this story. "2 of 36 comments" represents the number of current comments at or above the users' comment quality threshold.

The software that distributes the responsibility for content creation, commentary, and quality control across the community provides the users of Slashdot the tools they need to self-organize. While individuals follow rules strictly local to them (e.g., expressing preference for one type of content over another), these strictly local rules result in a complex macro-behavior that emerges within the system.

OSOSS, learning objects, and online learning

"But where is the learning?" one may ask. In this section we connect OSOSS, learning objects, and online learning by discussing a sample OSOSS interaction. Table 1 contains an excerpt taken from the PerlMonks website (http://perlmonks.org/) section titled "Seekers of Perl Wisdom." PerlMonks is an OSOSS where a variety of people learning the PERL programming language and working through the problems common to those learning the obtuse language interact and collaborate to teach each other and solve problems.

Unique ID by nlafferty on Jul 19, 2001 at 16:39 nlafferty has asked for the wisdom of the Perl Monks concerning the following question: I want to know how to generate a unique id for every row I enter into my postgreSQL DB. So that a unique id is specified to a variable, which I can INSERT into the row along with my other information.	A user named nlafferty asks a question about creating unique identifiers for data entered into a database.
Re: Unique ID by lhoward on Jul 19, 2001 at 16:46 The two easy ways to do this with Postgres. One is to specify the ID col. as serial type, which will cause it to	User lhoward responds with three alternative solutions to the question. One involves

be auto-incrementing (i.e. when you insert a row, it will automatically get a new, unique val in the serial col).
 	
Additionally, you can use a postgres sequence to keep track of the ID, and query it with postgres's nextval function whenever you need a new value:
 	
my $sth=$dbh->prepare("select nextval(?)");
$sth->execute("seq_name");
my $id=$sth->fetchrow();
$sth->finish();
 	
Of course, you can also do this the old-school way too (but its less efficient to do it this way): Have a table to store the last assigned ID. When you need an ID, lock that table, read the value out of it, write the value+1 back to the table, and then unlock it.
	using functionality already existing in the database (he is providing documentation). Another involves accomplishing the task by using additional software code (he is providing sample code that solves the problem). The final method is described as being inefficient and described in less detail.

Re: Re: Unique ID by nlafferty on Jul 19, 2001 at 17:05 So if I use a serial type then I do not have to use the sequence as well. Or do I have to use a combination of both?	nlafferty asks lhoward to expand on his first alternative.
Re: Re: Re: Unique ID by lhoward on Jul 19, 2001 at 17:28 The serial type creates and uses a sequence behind the scenes, but its operation is transparent to you. You do not need to create an additional sequence to use it. See... (using psql, Postgres's command line tool): test=# create table foo(ID serial NOT NULL,bar text, constraint foo_pk primary <program output removed to preserve space> I find postgres sequences to be most useful when you want to share one unique ID across tables and when you don't have a master table to store it in (or don't have a table that will always be inserted first). Or when you want to assign something outside of the DB (at	lhoward responds with an explanation including actual program input and output, and a description of the scenarios in which this alternative would be most effective.

least at the time of assignment) a unique ID.	
Re: Unique ID by lachoy on Jul 19, 2001 at 17:00 ObPerl: You can also use a wrapper like (plug plug) SPOPS (link) module to do this for you -- there is example code at this node (link). Chris M-x auto-bs-mode	User lachoy responds by linking to existing software that solves nlafferty's problem, along with sample code for integrating the software into nlafferty's program.
Re: Unique ID by lestrrat on Jul 19, 2001 at 17:07 If this unique ID does not have to be any thing in particular, you might as well use the oid column. oid is unique for every single row in the database, and is created when you insert a row. It's sort of a "hidden" field, so when you query, you have to do SELECT oid,* FROM table; # if you already know your oid.. SELECT * FROM table WHERE oid = x; This is so much easier than maintaining a sequence.... and is universal for Postgres.	User lestrrat responds with further database documentation, describing a solution already built into the database package. He includes sample code for accessing this functionality.
Re: Re: Unique ID by nlafferty on Jul 19, 2001 at 17:14 This is originally how I thought would be a good way to handle this. I'll give it a shot...thank you ;)	nlafferty thanks lestrrat and states that he will try this solution.
Re: Re: Unique ID by nlafferty on Jul 19, 2001 at 19:36 So how would I do a delete statement WHERE oid = "$oid" ?	nlafferty has succeeded in using lestrrat's solution and returns to ask a follow-up question.

Table 1. A sample interaction from an OSOSS. Portions of the interaction have been removed in order to preserve space; the full excerpt is available online at

http://www.perlmonks.org/index.pl?node_id=98134&lastnode_id=479. The right column contains our annotations of the interaction.

The resources referenced in the interaction in Table 1 are not employed in the traditional learning objects manner – "content prepackaged to teach a specific instructional objective." Instead, the resources themselves are relatively free of artificially imposed, embedded instructional strategies – the community members who initially identify the resources supply strategies and techniques for using the resources in a context-dependent manner. This utilization suggests a new definition of learning objects; one that changes from "any digital resource that can be reused to facilitate learning" (Wiley, 2000) to "digital tools used to mediate learning." We consider the focus on mediation (Wertsch, 1985, 1991) and distinction from facilitation to be significant.

The researcher is also prone to notice that the website software itself is mediating the problem solving process by taking questions and responses, displaying these in a threaded manner, etc. These affordances are important to consider – just as environmental variables such as access to food sources and proximity of competing colonies mediate an ant colony's ability to succeed, the OSOSS infrastructure itself plays a large role in the ability of the OSOSS to self-organize successfully. For example, individuals who use OSOSS without moderation and meta-moderation capabilities will self-organize differently from those whose environments provide these affordances.

Slashdot, the OSOSS described above, nearly self-destructed in early 2000 due to the noise-to-signal ratio among user comments. Comments such as "First post! I commented before anyone else!" and "Natalie Portman is sooo hot!", unrelated to the actual topic of discussion, began to drown out the more meaningful dialog. The moderation system evolved in order to help the community self-sustain. Meta-moderation evolved in response to similar needs. One can easily imagine a number of circumstances (such as a lack of technical sophistication by community members) that would have prevented this adaptation, resulting in the death of the system. In their ability to self-maintain while preserving their identity, OSOSS are autopoietic.

Because learning objects mediate the activities of individuals within an OSOSS, it stands to reason that the structure may be susceptible to the same weaknesses as the traditional methods of using learning objects. This is not the case, however, as OSOSS are rich in human interaction, can utilize arbitrary resources efficiently, and excel at mediating collaborative meaning making.

The most significant departure of the OSOSS from conventional learning objects approaches is that it relies on human beings to locate, assemble, and contextualize the resources. Although the tragedy of the commons (Hardin, 1968) would suggest that such voluntary collaborations are not sustainable over time, the emergence of the Internet, and specifically the Free/Open Source Software movements, have shown peer-to-peer communications technology's ability to put people in symbiotic, "you answer my question, I'll answer yours" relationships. The gift culture described by ethnographers of the Free/Open Source movements such as Raymond (1999) and Himanen (2001) is one explanation of this phenomenon. Another explanation is that a distributed expertise model obtains in sufficiently large distributed learning communities, meaning that because expertise exists across the community no individual community member is overly burdened with the primary responsibility for answering questions and providing feedback. As problems arise related to the expertise of an individual, that individual may or may not choose to provide help. If the community is of sufficient size, the distribution of expertise and effort provides timely problem solving support without unduly burdening any individual.

When learning objects are considered as mediational means that learners employ in problem solving and other types of activity, seemingly heterogeneous digital content chunks, assessments, simulations, and applications rotate into a single mediational factor. OSOSS provide a conceptual framework for a new method of indexing, discovering, combining, using, and evaluating digital educational resources.

- Indexing and Discovery: Learning objects are not cataloged with metadata and submitted to a central curator repository. Community members know of existing resources and local resource collections. Individual resources are discovered through “community queries” in which community members respond with pointers to resources they know about personally. When a sufficient portion of the community responds in this manner, the learner locates satisficing resources.
- Combination: Learning objects are not automatically populated into one of many instructional templates. Without the direction of any single grand architect, peers contribute relevant resources and descriptions of how they might be employed within the context of the initiator’s problem. Much like a colony of ants, peers autonomously build on one another’s work and create a satisficing resource structure without centralized direction (Bonabeau, Dorigo, & Theraluaz, 1999).
- Use: Learners do not sit through a temporal sequencing of resources and assessments linked to decontextualized instructional objectives. They employ resources provided by peers as mediational means in the solution of a self-selected problem or accomplishment of another self-selected goal.
- Evaluation: Learning objects are not critiqued out of an instructional context with a summative quality rating of 1-5. Learners evaluate the relevance and suitability of resources within a specific learning context. (Williams, 2001) contains an excellent description of the impasse created by attempting to apply current context-dependent evaluation methodologies to extremely decontextualized educational resources.)

We have argued above that current approaches to overcoming the “teacher bandwidth” problem, specifically those based on learning objects, suffer from a number of practical and pedagogical difficulties. As an alternative structure we introduced the construct of an online self-organizing social system (OSOSS). Reviewing a sample case from an OSOSS in light of previous learning objects criticisms reveals that none seem to apply. That is, it would appear that learning object use “in the wild” (educational resource use unmarred by instructional design and development methodologies), exhibits none of the weaknesses of contrived approaches to employing learning objects.

So what? Why are online self-organizing social systems important to the future of online learning? OSOSS include a large number of learners, yet scalability is not an issue. Learners are provided with meaningful learning support "anytime anywhere," yet the support is rich with human-to-human interaction. Learning objects are successfully embedded in a meaningful learning context, but the discovery and contextualization of the objects are done by humans – again without scalability becoming an issue. It is because these naturally occurring methods seem in some ways superior to existing approaches that we believe that online self-organizing social systems will be an integral part of the future of online learning.

The instructional design underlying OSOSS

Like any other instructional technology, the success of OSOSS in facilitating learning will depend on the degree to which instructional design principles are obeyed, whether this obedience is conscious or otherwise on the part of the learner. The sample OSOSS interaction in Table 1 reveals that community members are unknowingly employing methods from several instructional design approaches. In this section we present three brief comparisons of the PerlMonks excerpt and modern notions of instructional design.

Collaborative problem solving

Nelson's (1999) Collaborative Problem Solving process synthesizes literature on collaborative learning and problem solving to provide guidance to teachers and learners interested in learning through group problem solving. Nelson's process appears intact in the PerlMonks example above:

- Problem solving group membership is implied by membership in the community,
- learners negotiate a common understanding of the problem through a series of questions and restatements,
- learners' roles in the problem solving are implied as one learner poses the problem and responds with further clarifications, thoughts, or ideas,
- learners gather information from a variety of sources, including PERL modules, code samples, Postgres output, and Postgres documentation,
- a solution is agreed upon and implemented, and
- further questions are raised, beginning the problem-solving cycle anew.

Nelson summed up the important characteristics of OSOSS when she spoke of the attributes of the ideal CPS learning environment: "one conducive to collaboration, experimentation, and inquiry, an environment which encourages an open exchange of ideas and information" (p. 247).

Goal-based scenarios

Schank, Berman and Macpherson (1999) present goal-based scenarios as a teaching model that stresses student learning of "how to" over student learning of "know that," claiming that the model is "the ideal method of instruction, appropriate for any subject and any student age, and for both school and business" (p. 165). The methods of the goal-based scenario also exist intact in the PerlMonks example:

- The mission is not only somewhat realistic, it is student selected at the moment of greatest motivation,
- the "cover story" exists in the learner's life, and does not need to be concocted by an instructional designer,
- the student's role as problem solver is clear, as the student initiates the problem solving process herself,
- a variety of resources which provide the information necessary to complete the mission are supplied by the student and other group members, and
- feedback comes through the learner's application of the proposed problem solution.

Schank, Berman, and Macpherson (1999) may as well have been talking about OSOSS when they said that goal-based scenarios would succeed only "as long as they contain a rich amount of content, support interesting and complex activities, and are inherently motivating to the student" (p. 165).

Legitimate peripheral participation

While the PerlMonks example may seem haphazard and without the overarching guidance necessary to take learning in meaningful directions, Lave and Wenger (1991) called for this type of decentralization over a decade ago. In describing apprenticeship structures in a variety of settings, they conclude that resources are not generally structured for apprentices' use by a "master" – a broader community of practice into which the apprentice is working to insert herself assembles them.

> We argue that a coherent explanation of these observations [that masters are present in widely varying degrees in different apprenticeship communities, and that learning resources are generally structured by the larger community] depends upon *decentering* common notions of mastery and pedagogy. This decentering strategy is, in fact, deeply embedded in our situated learning approach – for to shift as we have from the notion of an individual learner to the concept of legitimate peripheral participation in communities of practice is precisely to decenter analysis of learning. To take a decentered view of master-apprentice relations leads to an understanding that mastery resides not in the master but in the organization of the community of practice of which the master is part…Similarly, a decentered view of the master as pedagogue moves the focus of analysis away from teaching and onto the intricate structuring of a community's learning resources (p. 94).

When we acknowledge the decentralized nature of learning, as in legitimate peripheral participation, it makes sense to build architecture to support such decentralization. Rogoff (1990) echoes appreciation of the role of putting novices in direct contact with each other.

> The apprenticeship model has the value of including more people than a single expert and a single novice; the apprenticeship system often involves a group of

> novices (peers) who serve as a resource for one another in exploring the new domain and aiding and challenging one another (p. 39).

The PerlMonks excerpt provides a clear example of peers attempting to structure resources in order to support an individual's learning, and providing additional support as necessary.

Instructional design super-theory?

Finally, while educators and instructional designers work to move "tried and true" pedagogical methods online, the self-organization analogy suggests another interesting perspective. PTAs and school boards bicker over the maximum number of students that can be placed in a traditional classroom because the teaching methods employed there work best with a certain number of students; for example, 30 or fewer. This inability to think "outside the box" is at least partially responsible for the scalability problem in online learning – moving "tried and true" classroom methods online dictates the maximum number of students that can engage in an online course. Conversely, computer models of self-organizing phenomena show that without sufficiently *large* numbers of agents morph genesis looks qualitatively different if it ever takes place at all (Johnson, 2001). This means that online self-organizing social systems could provide the foundation for a new instructional design science; namely, instructional design super-theory, which would deal with instructional design models in the spirit of Reigeluth (1983, 1999) for facilitating learning in very large groups of learners.

Potential problems with OSOSS and future research directions

OSOSS are no more the "cure to all instructional ills" than any predecessor instructional technology has been. And while they have the potential to improve online learning in meaningful ways (e.g., by overcoming problems of scalability while humanizing online learning by increasing levels of human interaction), OSOSS lacks a number of characteristics that are considered "strengths" of automated instructional approaches.

Challenges or difficulties:

- A standard curriculum may be difficult to impose on individuals in an OSOSS.
- Assessment of individuals may be difficult to carry out in an OSOSS.
- Required feedback may not be immediate in an OSOSS.
- Establishing identity and trust relationships within an OSOSS may take longer than in higher bandwidth channels (Ubex, 2001).

We see the prime areas for future research in OSOSS as twofold: more thorough ethnographic and discourse studies of existing OSOSS, including grounded theory studies that could guide the creation of software infrastructures to facilitate the development of these communities, and studies of ways around the weaknesses in OSOSS. The main obstacle to this research will be the large numbers of participants necessary for self-organization to occur, but the promise of the OSOSS approach merits the effort on the part of researchers.

Conclusion

In looking to the future of online learning we have suggested that existing approaches to overcoming online learning's key obstacle – teacher bandwidth – have critical weaknesses that will limit their success. Online self-organizing social systems, while not without their own weaknesses, exhibit strengths unseen in existing methods of learning facilitation. The OSOSS is thick with principles found in modern instructional design theories, yet creatively overcomes weaknesses in the very latest instructional technology fads. The OSOSS may also open previously unexplored areas of large-scale instructional design research, and provide fruitful linkages between instructional design research and that of other fields such as biomathematics, artificial intelligence, and complexity theory. As interest in problem-based learning (Albanese & Mitchell, 1993; Vernon & Blake, 1993) and online PBL environments increases, we believe that the OSOSS – or something like it – will play a significant role in the future of online learning, because the OSOSS is so well suited to facilitating and mediating problem-solving and problem-based learning.

References

ADL. (2001). Sharable content objects reference model. Retrieved July 23, 2001, from the World Wide Web: http://www.adlnet.org/

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*, 52-81.

Barritt, C. & Lewis, D. (2001). Reusable learning object strategy. Retrieved July 23, 2001, from the World Wide Web: http://www.cisco.com/warp/public/10/wwtraining/elearning/learn/whitepaper_docs/rlo_strategy_v3-1.pdf

Bloom, B. S. & Krathwohl, D. R. (1956). Taxonomy of educational objectives: The classification of educational goals, in Handbook I: Cognitive Domain. New York, Longmans, Green.

Bonabeau, E., Dorigo, M., & Théraulaz, G. (1999). *Swarm intelligence: From natural to artificial systems*. New York: Oxford University Press.

Brown, A. L. (1994). The advancement of learning. *Educational Researcher*, 23 (3), 4-12.

Clark, R. (1989). *Developing technical training: A structured approach for the development of classroom and computer-based instructional materials.* Performance Technology Press.

Driscoll, M. P. (1994). Psychology of learning for instruction. Boston: Allyn and Bacon.

Edwards, E. K. & Wiley, D. A. (Manuscript in preparation). An interpretivist view of the problems with learning objects.

Eriksson, D. M. & Wulf, V. (1999). Self-organising social systems: A challenge to computer supported cooperative work. *Cybernetics and Human Knowing, 6*(2), 1-4.

Hardin, G. (1968). The tragedy of the commons, *Science, 162* (1243-1248).

Himanen, P. (2001). *The hacker ethic*. New York: Random House

Hodgins, W. (2002). The future of learning objects. In D. A. Wiley (Ed.), The instructional use of learning objects. Bloomington, IN: Association for Educational Communications and Technology.

IEEE/LTSC. (2001). Learning objects metadata standard (current draft). Retrieved July 23, 2001, from the World Wide Web: http://ltsc.ieee.org/wg12/

Jacobs, J. (1961). *The death and life of great american cities*. New York: Vintage Books.

Johnson, S. (2001). *Emergence: The connected lives of ants, brains, cities, and software*. New York: Scribner.

Johnson, D. W., & Johnson, R. T. (1997). *Joining together: Group theory and group skills* (6th ed.). Boston: Allyn & Bacon.

Jonassen, D. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? *Educational Technology, Research and Development, 39*(3), 5-14.

Kristeva, J. (1986). *From symbol to sign*. In T. Moi (Ed.), *The Kristeva Reader*. New York: Columbia University Press.

Krugman, P. (1996). *The Self-Organizing Economy*. Oxford: Blackwell Publishers.

Lave, J., & Wenger, E. (1990). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Leont'ev, A.N. (1932). Studies on the cultural development of the child. *Journal of genetic psychology, 40*, 52-83.

Maeterlinck, M. (1927). *The life of the white ant*. London: George Allen and Unwin.

Mager, B.F. (1975). *Preparing instructional objective*s. Belmont, CA: David S. Lake Publishers.

Martinez, M. (in press). Designing learning objects to mass customize and personalize learning. In D. A. Wiley (Ed.), The instructional use of learning objects. Bloomington, IN: Association for Educational Communications and Technology.

Merrill, M.D. (1983). Component display theory, In C. M. Reigeluth, (Ed.), *Instructional design theories and models.* Hillsdale, NJ: Lawrence Erlbaum.

Merrill, M. D. (1999). Instructional transaction theory. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory.* (pp.397-424). Hillsdale, NJ: Lawrence Erlbaum Associates. [Is it Hillsdale or Mahwah? I thought they moved.]

Nelson, L. M. (1999). Collaborative problem solving. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory.* (pp.241-267). Hillsdale, NJ: Lawrence Erlbaum Associates.

OSDN (2001). The OSDN websites. Retrieved July 23, 2001, from the World Wide Web: http://www.osdn.com/advertise/osdn_websites.html

Pirolli, P. & Card, S. K. (1995). Information foraging in information access environments. *In proceedings of the conference on human factors in software (CHI '95)*, Denver, Colorado: 51-58. Retrieved July 23, 2001, from the World Wide Web: http://www.parc.xerox.com/istl/projects/uir/pubs/pdf/UIR-R-1995-07-Pirolli-CHI95-Foraging.pdf

Pirolli, P. & Card, S. K. (in press). Information foraging. *Psychological Review*. Retrieved July 23, 2001, from the World Wide Web: http://www.parc.xerox.com/istl/projects/uir/pubs/pdf/UIR-R-1999-05-Pirolli-Report-InfoForaging.pdf

Raymond, E. (1999). *The cathedral & the bazaar: Musings on Linux and Open Source by an accidental revolutionary*. Monterey, CA: O'Reilly.

Reigeluth, C. M. (1983). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. M. (1999). What is instructional design theory and how is it changing? In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory.* (pp. 5-29). Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. M. & Nelson, L. M. (1997). A new paradigm of ISD? In R. C. Branch & B. B. Minor (Eds.), *Educational media and technology yearbook* (Vol. 22, pp. 24-35). Englewood, CO: Libraries Unlimited.

Rheingold, H. (2000) Virtual Community: Homesteading on the Electronic Frontier. Cambridge MA:MIT Press.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.

Schank, R. C., Berman, T. R., & Macpherson, K. A. (1999). Learning by doing. In C. M. Reigeluth (Ed.), *Instructional-design theories and models*, Volume II (pp. 161-181). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Slavin, R. E. (1990). Research on cooperative learning: Consensus and controversy. *Educational Leadership, 47* (4).

South, J. B. & Monson, D. W. (2002). A university-wide system for creating, capturing, and delivering learning objects. In D. Wiley (Ed.), *The instructional use of learning objects*. Bloomington IN: Association for Educational Communications and Technology.

Ubex (2001). Who is real? Identity and online community. Retrieved October 1, 2001, from the World Wide Web: http://slashlearn.org/article.pl?sid=01/05/23/0513207

Vernon, D. T. A., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*, 550-563.

Vygotsky, L. S. (1962). *Thought and Language.* Cambridge MA: MIT Press.

Vygotsky, L.S. (1978). *Mind in Society*. Cambridge, MA: Harvard University Press.

Vygotsky, L.S. (1981). "The genesis of higher mental functions." In J.V. Wertsch (Ed.), *The concept of activity in Soviet psychology*. Armonk, NY: Sharpe.

Wertsch, J.V. (1985). *Cultural, Communication, and Cognition: Vygotskian Perspectives*. Cambridge University Press.

Wertsch, J. V. (1991). Voices of the Mind. Cambridge, MA: Harvard University Press.

Wiley, D. A. (2002). Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In D. Wiley (Ed.), *The Instructional Use of Learning Objects*. Bloomington: Association for Educational Communications and Technology.

Wiley, D. A., Recker, M. M., & Gibbons, A. (2000). The reusability paradox. Retrieved July 23, 2001, from the World Wide Web: http://rclt.usu.edu/whitepapers/paradox.html

Wulf, V. (1999). Evolving cooperation when introducing groupware: A self-organization perspective. *Cybernetics and Human Knowing*, *6*(2), 55-75.