

The Ecology of Education: Sustainability for the Future

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Section 1: The Origin and Development of Human Biological Needs'

"I don't need the Pope to tell me how the world works. To me, it functions like a huge clock or machine . . . and I can figure it out for myself. - René Descartes

The current educational crisis is one of perception. Society has changed greatly over the past 10,000 years, but contemporary human beings have had essentially the same genetic make-up throughout our quarter of a million years on earth. We are biologically and emotionally suited to interact in small bands, rather than large, impersonal groups. The gap between our biological origins and today's large educational environments does not produce the learning required to sustain humanity. Bringing our educational goals and practices into line with our biological heritage will create learning environments that prepare our children to make the hard choices required for a sustainable future.

For approximately 250,000 years, humans lived in groups of approximately 15 to 25 people, in which everyone was related by birth or marriage. We didn't farm, herd animals, or live in permanent dwellings, but roamed the land in nomadic bands searching for food. Each person's contribution was important to the survival and well-being of the group. For the most part, women gathered, men hunted, and they pooled their resources. The clear division of labor avoided competition between the sexes and ensured the equality of women and men. However, because animals have a tendency to run away or attack when they think someone is trying to eat them, it was the work of women that sustained the group. If anyone could claim superiority, it would not have been the men.

Anthropological and archaeological evidence suggests the simplest societies are generally the most egalitarian. Our ancestors depended on each other for support and survival. They made decisions by consensus after intense discussion and deliberation. We depended on each other for survival and support. We had no formal institutions or hierarchies. No one gave or took orders as his or her role in life. Authority and influence came to individuals as a result of skill, knowledge, or experience. To exercise leadership meant to influence others in community decisions. Old, young, men, and women got involved when decisions had to be made.

In the hunter-gatherer culture, education took place in small groups. It was personable and hands-on. People regarded the physical, mental, and spiritual aspects of life as interconnected. It was understood that things cannot be fully explained by taking them apart and putting them back together. Learning was holistic and integrated. Education was life and life was education.

The human experience of living in small, personable groups for the vast majority of our time on earth has prepared us to interact most effectively in close-knit, interdependent communities in which everyone feels respected, recognized, and acknowledged as important. We want to be liked and be part of something significant and useful. We are fearful of being different, of being ostracized from the group. We like to belong, be trusted, and feel that others can be trusted. We feel good being surrounded by people we can count on, knowing what is going on, and having a say in decision-making. We want to be kept in the loop and have a sense of control over our lives and our destiny. We want to make things happen, not just watch them happen.

The adoption of agriculture practices 10,000 years ago made it easier for humans to live permanently in larger and larger groups. A less nomadic life allowed people to accumulate possessions and store large quantities of food over time. Deep class divisions emerged as the new elite controlled the wealth and others experienced poverty for the first time in history. Deep class divisions led to specialization, hierarchy, imperialism, slavery, malnutrition, starvation, and war.

Epidemics could not take hold in scattered and constantly moving small bands, but tuberculosis, measles, diarrheal diseases, and bubonic flourished in the newly-created cities. Malnutrition and starvation became more prevalent. Human skeletons from Greece and Turkey from the end of the Ice Ages had an average height of 5' 9" for men and 5' 5" for women. With the adoption of agriculture, height crashed, and by 3,000 B.C., average heights reached a low of 5' 3" for men and 5' for women (Diamond, 1987).

In human culture after the introduction of agriculture, education was specialized according to socioeconomic group. Each group had a designated role in life as a peasant, craftsman, or lord. Preparation for these roles took place in guilds and apprenticeships or through tutors and mentor-protégée relationships. Education became rigid, bureaucratic, terminal, and provided no social mobility.

The Industrial Revolution (circa 1760 or 1830 to the present) was grounded in the ideas of René Descartes (1596-1650) and Isaac Newton (1642-1727), which redefined how the world works and is organized. All systems, including people, were thought to be orderly, uniform, and controllable by isolating and sub-dividing their basic components into ever smaller parts. Because systems, including people, were believed to function in a linear, step-by-step manner, they were thought to seek equilibrium and stability and, at least theoretically, to be as predictable as clockwork. Based on this perception of the world, hierarchy and bureaucracy became mechanized and over-specialized. Social isolation and personal disintegration became commonplace. Environmental contamination and new diseases emerged.

In the industrial age, education was expensive. Very few children actually went to school because only the wealthy could afford it. Poor children worked at home rather than attend school. Boys were educated but not girls. Girls stayed home to learn to care for a home and family. Education reinforced the status quo of hierarchy and socialization, ensuring that an oligarchic few controlled the wealth and made all the decisions.

In today's environment, education is more egalitarian, but at the same time burdened with pathological consumerism, ubiquitous propaganda, the banking method of education, schools functioning like factories, absenteeism and dropouts, drug and alcohol addiction, and an increase in learning disabilities. We constantly bemoan the state of our schools but seem to have little sense of what to do about it.

Our perceptions about who we are as human beings are key to understanding what can be done to prepare ourselves and our children for a sustainable future. While 10,000 years of exposure to agriculture and 200 years of exposure to industrialization have had an impact on our species, our biological make-up is still essentially that of our hunter-gather ancestors. We are genetically predisposed to live most effectively in small personable bands of approximately 25 individuals, rather than in large, impersonal groups. The gap between the environment in which we are genetically inclined to thrive and the ways we are required to behave in large organizations (such as schools) make us miserable because these are not our natural environments.

A sampling of the biological needs we developed during our time as hunter-gatherers (Figure 1) represents shared fundamental understandings about what allows children to thrive. These biological needs address the emotional well being of every human and are prerequisites for individual self-esteem, interpersonal trust, and the viability of human communities. When the biological needs of a human being are not met, psychological, emotional, and sociological dysfunctions are soon to appear, leading to interpersonal conflict and societal disorder. In other words, these needs are every bit as crucial as our need for food.

Figure 1: A Sample of the Biological Needs of Human Beings

As a result of our lifestyle as hunter-gatherers, we human beings have the following biological needs:

We want to belong.

- To feel we are a part of something larger than ourselves, that we belong to a place and to the people in our lives.
- To be recognized and acknowledged as important and making a contribution to the whole.

We want to be liked.

- To be respected for the people we have come to be.
- To be appreciated for our similarities to and differences with others.
- To be not ostracized by our family, friends, and community.

We want to be in community with others.

- To interact socially with other human beings on daily basis.
- To communicate clearly within our family and community.

We want to feel safe and in control of our lives.

- To feel safe from intrusion or violence by other beings, whether human or other animals.
- To have a sense of control over ourselves and our destiny.

We feel good being trusted and surrounded by people we can count on.

- To feel we are trustworthy and can be depended upon by others.
- To feel competent in what we do in school, at work, and as members of our family and community.
- To feel we are surrounded by competent, trustworthy people we can count on.

We want to be kept in the loop.

- To be included and part of decision-making that affects us.
- To make things happen rather than just watching them happen or having to ask what happened.

We want to learn.

- To learn from the expertise of others through hands-on experience.
- To have access to mentors who guide us with tangible examples and by smoothing the way for us.

We want to be an active part of our world.

- To be active physically and creatively in work and play.
- To feel that we are part of nature and that nature is part of us.

To meet our human biological needs, we must go "back to the future" to rediscover our fundamental human nature. The African concept of Sankofa "beckons us to reconcile our past with our present" (Bordas, 2007, p. 23).

[Sankofa is] a mythical bird from West Africa who looks backward, symbolizes the respect African Americans have for the insight and knowledge acquired from the past. Sankofa reminds us that our roots ground and nourish us, hold us firm when the winds of change howl, and offer perspective about what is lasting and significant. Although Sankofa rests on the foundation of the past, its feet are facing forward. This ancient symbol counsels us that the past is a pathway to understanding the present a creating a strong future (Bordas, *ibid.*, p.28).

As human beings who are still biologically what we were as hunter-gatherers, we are failing to meet our fundamental biological needs. The current crisis in our environment, our culture, and our ways of educating children came about because our ways of living go against our own human nature. The solution is not to return to our origins as hunter-gatherers but to go "back to the future" to acknowledge that the biological needs we developed as hunter-gatherers still apply and to develop ways to meet those biological needs in the world that exists today. For the future of our grandchildren and their grandchildren, it is imperative that we understand our nature as human beings so as to be able to develop environments and social structures that encourage us

to behave accordingly. When our behavior draws on our biological strengths, we have the best chance of preparing for a sustainable future by creating sustainable communities that no longer damage the earth.

Section 2: Human Biological Needs and the Purposes of Education

"The central task of education is to implant a will and facility for learning; it should produce not learned but learning people. The truly human society is a learning society, where grandparents, parents, and children are students together." - Eric Hoffer²

Education reflects what we do in the rest of society. Human cultures throughout history have viewed the purposes of education differently; the Spartans, Romans, and Mayans all had different perceptions. Modern day debates about education are equally diverse. When human beings consider the goals of education, they are like visually impaired people trying to describe an elephant. Each of us reaches out to touch a different part of the education elephant. One touches the elephant's trunk, another the ears, or and yet another the tail. As correct as our perceptions may be, they are all incomplete. All of us are limited in what we perceive and understand about education, its purposes, and the most effective ways to accomplish those purposes.

Some proposed purposes of education from Western cultures are offered in Figure 2.

Figure 2: Purposes of Education

- "To produce citizens." - A previous Archbishop of York before a group of English headmasters
- "To gain knowledge to change the world for the better." - The Roman Catholic Church
- "To develop the whole person of the student." - The Initiative for Global Development, a national alliance of business leaders championing effective solutions to global poverty
- "To be the proper cultivation of the gifts and talents of the individual through the acquisition of knowledge, . . . to teach us how to give proper service to self, family, community, nation, and then to the world." - Louis Farrakhan
- "To provide the opportunity for each child to grow into his or her full capacity." - The U.S. Department of Education
- "Any act or experience that has a formative effect on the mind, character, or physical ability of an individual. . . the process by which society deliberately transmits its accumulated knowledge, skills, and values from one generation to another." - Wikipedia
- "An educated person is someone who is wise to the world and knows and understands social graces while protecting their dignity in the process" - Conventional Latin American answer
- "The acquisition of knowledge, the reading of books, and the learning of facts." - Conventional U.S. answer
- "To give children a desire to learn and to teach them how to use their minds and where to go to acquire facts when their curiosity is aroused." - More Contemporary U.S. answer

And yet, many current thinkers acknowledge that our current educational systems too frequently fail to achieve these purposes.

- "If the purpose of school is that children may learn, then school is quite evidently not working." - Charles Eisenstein³
- "A person who is schooled only to pass the test . . . is ill prepared to cope with today's rapidly changing world. Something more is needed to make the student successful in today's world." - Randall Bass⁴

We assert that the primary reason that today's educational efforts do not produce effective learning is that we humans are no longer in touch with our biological heritage. Regardless of the human culture in which they occur, educational purposes go awry when we fail to understand the biological needs that motivate and sustain our behavior as human beings. As creatures with bodies and emotions still largely like those of our hunter-gather ancestors, we humans require environments that reinforce our biological need for living in close-knit, interdependent communities in which everyone feels respected, recognized, and acknowledged. When we live and learn artificially, our institutional environments make us feel inadequate and distressed. Our biological heritage causes us to do poorly in large, bureaucratic hierarchies with one-way communication, lack of democratic processes, and dehumanizing factory or business metaphors used to organize and manage students and their schools. We cannot educate effectively using strategies and techniques that go against the grain of those we are trying to educate. For our children to understand themselves and sustainably interact with the rest of the world, they need to understand that they are intimately connected with everything that surrounds them.

The educational process is an emergent quality resulting from the interaction of students and teachers in a learning environment. Emergent qualities are more than the sum of their parts. Emergent qualities require interaction and do not emerge out of static things. They are qualities that emerge from the elements of a process. For example, it is the careful and considerate combination of characters, plot, setting, theme, and point of view that determines whether or not a story can be considered a work of art. Similarly, a musical note played individually has a particular quality, but when three notes are played in a triad chord, the chord has qualities that do not exist in any of the three notes. If you line up the words of a great poem on a page, all you have is a list of common words; the essence of the poem is lost. It is only by putting the words or notes together and getting them to interact with each other that we create art and music that inspire, provoke us to think, and demand the deepest of feelings.

Schools and universities exemplify the same emergent qualities. Carlos, one of the two authors of this paper, tells the story of an undergraduate who was accepted to a prestigious university and on her first day noticed that there was a minibus tour of the campus. On the tour the driver pointed out the student union, various classroom buildings, the sports center, and the mall. As the tour continued, the student became more and more anxious and finally blurted out, "Yes, yes, but where is the university?" A university is far more than its physical environment. Universities that have suffered natural disasters have quickly understood that despite their physical losses, the university can be anywhere that students, faculty, and learning come together. A learning environment is an emergent quality that coalesces out of the interaction of people in their various roles, their personalities, purposes, and resources.

Our crisis of perception has prevented us from seeing the learning environment as one that must support and sustain human biological needs. A change in perception allows us to go back to our origins, look again, and see the educational process in a different way. All the elements of an educational system -- students, teachers, administration, buildings, classrooms, curricula, textbooks, technology, and resources -- interact to create the emergent qualities of a learning environment. When the emergent learning environment does not allow students to feel respected, recognized, and acknowledged as important, when students are fearful of being ostracized for their differences, when they do not feel trusted and cannot trust others, when they don't have a sense of control over their lives and their destiny, then neither the students nor society can fully benefit from their education.

Our educational system too often offers a semblance of meeting human biological needs, giving something that looks like respect and recognition, but doing so artificially. Both authors of this paper remember high school pep rallies as an example -- activities that are designed to inspire school spirit but can be artificial and contrived. Students who feel strongly about their needs not being addressed at school may be easily attracted to gangs that also appear to offer them respect and recognition. Others may be lulled into passivity, going through the motions of school but learning very little of use to their future.

The teacher is the key element within a learning environment, the one most responsible for developing and sustaining the context of learning. Teachers determine the quality of student learning by the way they teach, their skills and how they put them to use, and the way they structure the physical learning environment. It is not so much the teaching method that makes the difference, but what teachers bring to the classroom with their methods. As one of Carlos' teacher education students noted recently, some professors just come in and lecture, while others may lecture, but they also interact with students and bring in props to create a dynamic learning environment.

The other author of this paper, Janice, recently assumed responsibility for a class of students during the original teacher's maternity leave. Janice was new to the college and there were many administrative and curricular responsibilities to assume, but the most crucial factor in making a successful transition was establishing connections with each of the students, beginning with learning their names, and continuing with creating a delicate balance between individual student personalities and aspirations, course content and activities, and the systemic expectations that culminate in grades. The key to establishing this all important balance is placing the needs of students first. Does each student feel that he or she is a valued part of the class? Do students feel acknowledged for their contributions? Do they feel included in what is going on? Can they trust the teacher and their classmates? Do they have a way to feel competent in what they do in class?

Students are the ones who can tell us if their biological needs have been met or not. School cannot be just something that is done to them. In a productive learning environment, the students are an active component of the process, sharing accountability by fulfilling their roles as learners, providing feedback about what it feels like to function in the learning environment, and helping teachers discover how the learning process could be done differently and more to their benefit.

Our students still possess many of the same biological and emotional needs as our hunter-gatherer ancestors. Our ancestors needed to belong to something larger than themselves. They lived in one small group 24/7 for their entire lives. Each individual could make small decisions on their own, but other decisions, such as where the group would go next, required constant engagement with and alignment to the rest of the members of the group. These decisions took place within an ecological environment that provided predictable familiarity to the group. Coastal people stuck to the coasts; mountain people to the mountains; forest or jungle people to the forests or jungles.

Our ancestors understood that for a small band to survive, everyone's talents were important. The small groups needed everyone to fulfill their roles in the group. Everyone had to know something about how to do everything and everyone had to be an expert at something, whether it was making arrowheads, gathering medicinal plants, or navigating travel by the stars. Recognition of each person's skills was real in that the survival of the group depended on those skills. Respect from other group members came from fulfilling one's role dependably and effectively. Each person had a relatively accurate sense of the extent of their abilities and the degree to which their skills supported overall group survival.

Group members who behaved in unreliable ways were in danger of ostracism or even exile. A person who behaved in unreliable ways would eventually be ostracized for the good of the group. Exile from the group meant eventual death. Each person was motivated to be a group member in good standing in order to assure their survival. Being a member in good standing meant finding ways to be of value to the group through the development of skills and the fulfillment of crucial roles.

Groups were more likely to survive when skills were distributed across the members of the group, with each member taking the time to specialize and perfect their unique skills. Bands of hunter-gatherers were like a "Mission Impossible" team. Each person had their role in developing one or more of a variety of talents necessary for the group to survive in a hostile environment. The person who made arrowheads was expected

to do his or her very best, as was the person who gathered medicinal plants and the person who navigated travel by the stars. The group trusted its member to embrace their roles in supporting group survival and success. If a member failed to fulfill his or her role, group survival could be threatened. Each group member needed to know that he or she could depend on each of the other members of the group to be competent and reliable to the fullest extent of their abilities.

A major reason for living in small bands was the protection they afforded from predators and other environmental hazards. Group members needed to know that other members of the group would defend them if necessary and do what was possible to provide safety for all. At the same time, human beings understood that we are part of the natural environment. Great emphasis was placed on living in harmony with the nature and subject to its laws.

Group members were kept informed and included in group decision making. The small numbers in each group allowed everyone to sit together to discuss important decisions to be made. Being kept in the loop about group activities and decisions reinforced each member's trust and confidence in the other members of the group. Each group member depended on the group, and the group depends on each of its members. Being included in group decision-making helped each person feel they had some control over their destiny.

The knowledge and skills of group members were passed down through the generations by older group members mentoring younger members. The group had to pass on its skills in order to survive. It was natural to have one or more mentors. Mentors understood the importance of passing on their skills to the next generation. The most effective way to develop the skills of each new generation was through hands-on experience. Children watched their elders and learned by imitation. They used their senses to absorb new skills implicitly. What they learned became fully integrated into their attitudes and behaviors for the remainder of their lives. Each generation came to understand that the group depended upon them to use their new found knowledge to think strategically and take effective action as the need arose.

Finally, members of each small band were family and community to each other. No one could isolate themselves and survive. Clear communication and social intimacy were required for each group member and the group as a whole to thrive. Researchers have claimed that the actual work required of any group member occupied only a part of each day. The large amount of time available for rest and recreation offered a wealth of opportunities for positive relations among group members. Strong affiliation and regard among group members increased the likelihood of group survival.

Our human culture developed strengths over the many years before the advent of agriculture that are now hidden from us. In the words of Jerome Brunner, We are now trying to reconnect things that "should never been pulled asunder."⁵ We need to re-integrate the traits of our hunter-gatherer ancestors that continue to be ours. Our current culture has divided everything into disciplines and sub disciplines to the extent that we can no longer see ourselves as we still are. In the sixteen years of schooling many of us experience, we learn about biology, chemistry, psychology, and economics, but no one ever tells us that being out of work (economics) can create all kinds of mental dysfunction (psychology) that can cause stomach acid to increase (biology and chemistry) that can cause further disease and the need to heal it (medicine). But we can't just cut out the problem and expect to return to health. We need to consider an integrated solution of exercise, nutrition, positive thinking, and a low-stress lifestyle. Things are more complex than we imagine. We came to the current crisis of education misunderstanding who we are and how we got here.

The authors of this paper are like everyone else in reaching out to touch the educational elephant in our midst. Nevertheless, we believe that most human beings today could agree that the goals of education are to help us understand who we are, comprehend the world we live in, learn to navigate our world, and leave it a little better than we found it.

Section 3: The Ecology of Education

"Old beliefs die hard even when demonstrably false." - Edward O. Wilson⁶

S. N. Goenka, a teacher of Vipassana meditation, tells the story of a simple man who worked as a sailor on transoceanic ship. On one of voyages, there was a college professor who offered lectures on different topics to enlighten and entertain the passengers and every night the sailor found time to attend. The first night, the professor singled out the sailor to ask him, "Old man, you know about astronomy, don't you?" The old man replied, "I'm sorry, sir. I don't know about astronomy." "Then you have wasted a quarter of your life," the professor concluded. The second night, the professor lectured on anthropology and again probed, "Old man, you know about anthropology, don't you?" Again, the old man replied, "I'm sorry, sir. I don't know about anthropology. I've never studied those things." and the professor said, "Then you have wasted half of your life." On the third night, the professor asked him, "Old man, you know about meteorology, don't you?" The old man replied, "I'm sorry, sir. As I said, I've never studied those things. I don't know about meteorology," and the professor said, "Then you have wasted three quarters of your life." Later that same night, the sailor knocked on the professor's door and said, "Professor, you know about swimology, don't you?" The professor answered, "Swimology, what is that?" "Can you swim, sir? We've hit a reef. The ship is going down. You need to be able to swim." "No, I don't know how." "I am sorry, sir. In that case, you have wasted ALL of your life."

Education accomplishes its purpose when it connects learners with what is important to them. The professor's knowledge of each separate science proved useless as he contemplated swimming for his life. Theory and practice need to work together to apply to life's problems. Our approach to the ecology of education begins with an understanding of human biological needs and extends to the qualities and characteristics of educational practice that emerge from these needs. For our education institutions to thrive, teachers and students must interact with an ever-changing complexity of factors to focus on what each learner needs to succeed in his or her own life.

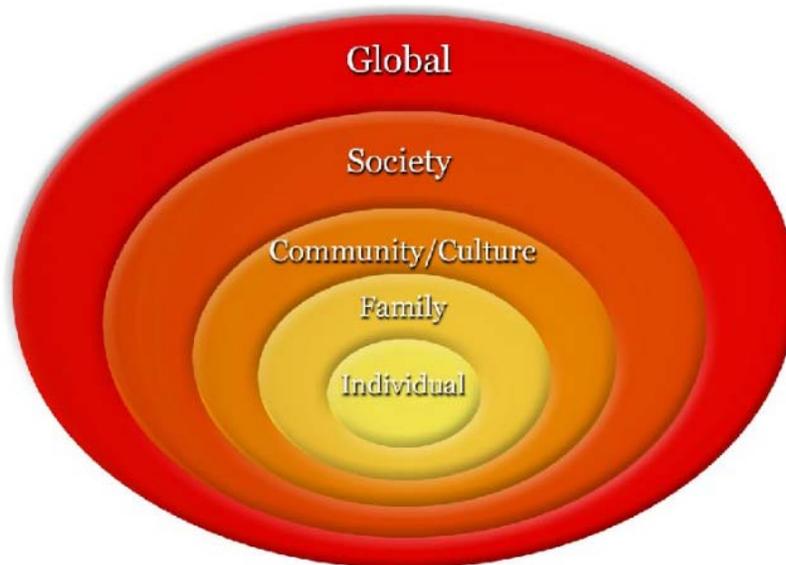
Educational environments can be likened to natural environments. For example, trees have roots, branches, and leaves. The roots require fungus to aid in absorbing water and the fungus requires tree roots to survive. Over its lifetime, the tree's branches produce thousands of flowers and ultimately fruits, only some of which result in offspring. The flowers are pollinated by insects, which use the pollen and nectar for food. The fruits are eaten by birds and small mammals, which also disseminate the seeds far beyond the reach of the tree. When the tree dies, its trunk, roots, and branches disintegrate, creating richer soil for new trees to come. The emergent qualities of the tree develop from the interaction of multiple components of the tree with its environment.

The ecology of education suggests a search for ways to practice education as "an 'organic cultivation' of knowledge rather than as an industrial reproduction and transfer of science and information" (Turpeinen 2005, p. ix). The qualities of education emerge from the interaction of students and teachers within the contexts of their physical location, resources, curricula, and society, all in relation to the biological needs we humans have inherited from our hunter-gatherer ancestors. It is the intricate interaction of these many factors that determines the emergent qualities of each child's education and the degree to which that education addresses what is important to him or her in living life.

As Fritjof Capra (1997) asserts, "The more we study the major problems of our time, the more we come to realize that they cannot be understood in isolation." The factors of students and teachers and their classrooms, resources, curricula, and society do not contain the qualities that emerge out of their interaction, nor can they be studied in isolation in order to understand these emergent qualities. Instead, these factors must be studied in relation to their interaction and influences upon each other. In the same way, the qualities that emerge from these factors must also be studied in relation to their interaction and influences upon each other and with the original factors.

Eggleston (1977) began his examination of the ecology of the school with a rather mechanical explanation of a system that is far more organic and complex by identifying three ecological themes: 1) The unevenness "within a national system of education, between and within local authority system and between and within local schools," 2) "The complex pattern of interrelated factors that contribute to the creation, maintenance, repair, and reproduction of the educational ecosystem," and 3) Each individual has his/her own perception and acts accordingly. Eggleston's work prepared the ground for Urie Bronfenbrenner and his followers (Huitt 2009) to develop a systemic model of the complex interaction of emergent qualities of education. In this model (see Figure 3), each individual student interacts with and is most immediately influenced by family and community/culture, including his or her school, faith community, peer group, and culture with which the family identifies. The influences of society, which include available choices in transportation, entertainment, and media, interact with and are filtered through the student's family and community/culture. Societal, international, and global influences interact with and are filtered by the influences of society and of the student's family and community/culture.

Figure 3: A Systems Approach to the Study of Human Behavior (Huitt, *ibid*).



We humans are ecological systems ourselves and to survive we depend upon the ecological system of our planet. Due to innovations of agriculture and industrialization, we have modified our perceptions such that we no longer remember that we have biological needs beyond the obvious ones of food, shelter, and clothing, and that we as a species share accountability to provide these needs for ourselves. Our current ways of understanding human thinking and behavior have proven insufficient to renew our distorted perceptions of ourselves. Similarly, the interaction of the systemic layers of influence in an ecology of education cannot be captured by the mechanistic, linear thinking of Descartes and Newton. Fortunately, for the first time in human history, science is beginning to catch up to our better intuitions to yield new ways of perceiving that go back to a hunter-gatherer understanding of science and the ways of human thinking. We propose that these resurrected ways of understanding be applied to education as tools to help our students create new perceptions of themselves in order to learn how to live sustainably. Accordingly, we turn to the new science of non-linear dynamics, also known as chaos theory or complexity theory, for a more effective methodology to use in tracking and understanding complex ecological systems, and to the closely related Triadic Theory of Human Mental Functioning and Behavior (Torre 1984, 1987, 1989, 1993, & 1995), for more productive ways of helping our students learn and internalize the concepts and practices of sustainability.

Nonlinear dynamics transforms a linear worldview into one that better accommodates chaos and complexity. Nonlinear dynamics describes the world in a way that is infinitely closer to how life presents itself than the classical sciences do. Figure 4 highlights the differences between linear thinking and a nonlinear worldview.

Figure 4: The Linear and Nonlinear Worldviews

(Adapted from a chart originally conceived by Karen VanderVen for inclusion in VanderVen & Torre, 2000)

Linear World View	Nonlinear World View
Desires simple, rational solutions to problems.	Works to recognize the complexity of situations and change, without simple solutions which can exaggerate the problem.
Seeks precise prediction.	Recognizes that many occurrences are sudden and unpredictable.
Amount of input is directly proportional to the expected output.	Small inputs may have much greater and more significant output.
Effective action is literally sequential, one step after another.	The reality of action - including learning - is non-sequential, from random to patterned.
Entities are additive: more is essentially "better."	Entities are variable, "too much" or "too little" can have negative effects.
Seeks and values stability and equilibrium as "ideal state."	Recognizes that instability and unpredictability are the norms, not the exceptions.
Variables operate independently, <i>e.g.</i> , are not affected by context.	Variables are affected by, and in turn, affect their context.
Views entities and phenomena as a "unity"	Views entities and phenomena holistically as open, dynamic systems.
Takes apart to understand component pieces (reductionism)	Seeks to recognize connections among system components.
Seeks to address problems by direct control.	Recognizes that control is not only undesirable, but essentially impossible, and seeks to influence rather than dictate.
Systems are affected only by forces from "without."	Systems are affected and changed by internal forces that organize themselves, as well as external forces.

A nonlinear worldview helps us understand and work with the complexity of the ecology of education, which by its very nature, behaves in an unpredictable and fractal way. Every educational variable interacts with every other variable, and although what emerges from their interaction can be predictable in a global way, the exact repercussions of what emerges locally are far less predictable. The more we immerse ourselves in the ecology of education, the more complex it becomes. Nonlinear dynamics tells us that complexity is on the edge of chaos and that that is the place where change begins to emerge. In order to change our educational environment, we need to understand the interaction of its variables well enough to know when and how to stimulate change and then be wise enough to wait with patience as the environment self-organizes to allow new qualities to emerge and adapt themselves to the local environment.

When we look at educational environments from a complex, ecological perspective, we can also begin to mediate the severity of repercussions that result from seemingly harmless factors and conditions. These repercussions are unpredictable, not only because of the number of interacting variables and the complexity of their interaction, but because of interaction itself. There are so many interactions between variables that they are impossible to track, and when we do try to track them, they complete their interaction almost before we

begin. To illustrate with a more familiar example, if you have a sister, both you AND your sister will be different than you each would have been if she did not exist, simply because of the interaction between the two of you. When you interact with your sister, the very fact that both you and she exist changes you, your sister, your parents, and everyone with whom you and she interact. It is the interaction itself that changes the behavior of the things that are interacting and makes that behavior unpredictable.

To better understand the ecology of education, we look for patterns of interaction. In nonlinear dynamics there are three possible types of patterns: a single point in space and time, a cyclical pattern, and a fractal pattern. The single point represents a state of non-change (total inertia). The cyclical pattern can be represented by the ideal movement of a pendulum in perfect balance (something which never occurs naturally). Most patterns, however, are chaotic or fractal in that they are visible and repeat at different levels, are predictable at a global level, but cannot be fully predicted at specific or local levels.

Using classical science, Newton proved the universe was stable by charting the behavior of two bodies orbiting around each other. In nonlinear dynamics, the two bodies represent a cyclical pattern, one that presumably continues without end through eternity. But when Newton added a third body to the interaction, his equations could no longer predict the stability of the system. We know that our solar system has many more bodies that all interact with each other, yet there is at least a semblance of stability there. The classical sciences cannot demonstrate that any system is stable beyond the interaction of two bodies. When Henri Poincaré was finally able to use the nascent science of nonlinear dynamics to predict the movement of a group of celestial objects based on their gravitational interaction, he described the calculations as looking like a tangled ball of string, in which there were many similar patterns, but no one pattern ever repeated itself exactly.

These patterns that never repeat themselves exactly are known as "fractals." Much of nature exhibits fractal structure that is "self-similar." There are many examples from ordinary life that illustrate fractal behavior. If you cut off one of the branches of a broccoli plant, the branch resembles the whole plant. If you do the same with a branch of the branch, you will note that it resembles the branch, which resembles the whole plant. In another example, if we pour sand into a container, we can predict that it will take on a bell-shaped curve and that that curve will eventually collapse. We cannot, however, predict the precise moment at which it will collapse, only the range of time in which it is most likely to collapse. We can predict the global pattern but not the exact local behavior of that pattern. Similarly, July in the northern hemisphere is likely to be hot and humid, but on any specific day at any specific place, we have no idea what the exact temperature and humidity will be. In an educational environment, an example of a fractal might be discovering that a global change in strategy decreases the overall student drop-out rate, but being unable to predict exactly how far the drop-out rate will decrease when a particular school district applies that strategy.

Morrison (2002) summarizes the role of complexity thinking on schools and their leadership.

Schools should be regarded as self-organizing, complex, emergent, non-linear organizations. . . . The leadership task becomes the management of micro-politics and of moving the members of the school from a competitive, secretive, isolationist and procedure-driven mentality to a collaborative, interdependent, group- and team-based network, with devolved decision making and its accompanying responsibility and accountability.

We need to use nonlinear dynamics as a tool to better understand the complexity of our schools, their basic patterns, and how and why they function. Better understanding will aid educational leaders in determining global strategies to apply locally by stimulating the school environment at just the right time and place to allow it to self-organize and permit transforming qualities to emerge. We assert that a key strategy will be to encourage a return to focusing on the biological needs of students and teachers in considering how to change our perceptions and practices of sustainability.

The principles of nonlinear dynamics can assist teachers and teacher educators in designing educational mediations to stimulate perceptions and practices in a way that addresses the human biological needs of students. Figure 5 describes the characteristics of mediations that are most likely to succeed in this regard.

Figure 5: Nonlinear Principles for Designing Effective Educational Mediations

(Adapted from a chart originally intended for inclusion in VanderVen & Torre, 2000)

- *Systemic*: The mediation must affect the system (e.g. student, classroom, school, or district) as a whole, with multiple components connected to and interacting with each other.
- *Evolutionary*: Time must be allotted for variables to interact and for new qualities to emerge and have an effect.
- *Non-linear*: The mediation must be complex, encourage variability, recognize unpredictability, and connect with other mediations.
- *Sensitive to Initial Conditions*: A small bit of difference at the beginning of a mediation can make a huge difference as the mediation evolves (i.e., The Butterfly Effect).
- *Detects Patterns of Behavior*: The mediation must identify patterns of behavior (unchanging, predictable, or chaotic) in order to determine how to mediate them.
- *Fractal*: The mediation must have similar manifestations at different levels of the system (e.g., student, classroom, school, community).
- *Self-organizes*: The mediation increases in complexity over time and be flexible enough for the system (e.g. student, student and teacher, student, teacher, and class) to set its own parameters for change.
- *Far from Equilibrium*: The mediation requires irritation as well as stimulation to unbalance previous conditions and to permit new qualities to emerge.
- *Entrainment*: The mediation must synchronize the system identified for transformation (e.g. problem student) with other systems that can assist with the transformation (e.g. peer counselors).
- *Nudges*: The mediation should not simply 'keep doing the same thing,' but instead nudge, rather than control, the system identified for transformation (e.g. ineffective teacher) by introducing unexpected components (e.g. assigning a mentor).
- *Recognizes Recursion*: To ensure that the impact of a mediation endures, it must recognize reoccurring patterns of interaction and incorporate them into the evolving context.

One example of focusing on biological needs would be to influence teacher education such that those who educate future teachers become willing to address the human biological needs of teacher candidates and overtly encourage teacher candidates to address the biological needs of their future students. The University of Minnesota Preparing Future Faculty (PFF) Program⁷ that Janice founded and directed for ten years is an example of this infusion. The program is systemic in its connections to national PFF resources and to local colleges and universities that provide mentorships for prospective new faculty. Minnesota PFF also systemically influences each graduate program by encouraging graduate students to participate and bring their new knowledge and skills in teaching and the nuances of the faculty role back to their disciplines. The program is evolutionary in planting seeds that have been allowed to develop over time, resulting in a network of new faculty dispersing across the country to further influence their peers and students. Minnesota PFF has used a complex array of strategies over time to influence prospective faculty to see their students as fellow humans struggling with their own ecological contexts. The results of these strategies have surprised and delighted PFF staff by their unpredictability and connectivity to other influences for change in graduate education.

PFF has understood from the beginning that small changes can lead to huge differences in behavior. For example, peer discussion of the impact of active learning can reinforce teacher willingness to try out new teaching methods, which in turn allows new faculty who see the results in their students to change their perceptions about the nature of learning. These self-similar, fractal patterns of graduate student behavior allow

PFF staff to develop curricula that continues to challenge each subsequent peer group to change their thinking about learning and practice their new beliefs in their own classrooms. The complexity of the PFF model self-organized over time to produce new innovations in the PFF curriculum and mentoring process to more effectively transform the experience and skills of prospective faculty. At times the program influences PFF students to the edge of chaos, particularly when the age-old practice of lecture-centered teaching is challenged. This instability is tempered by the support of faculty mentors who are experienced in using more active methods of teaching and learning and who "nudge" their protégées into the unfamiliar territory of putting student needs ahead of content delivery. With each new cohort of prospective faculty, the process of transformation reoccurs, each time with new and surprising patterns and discoveries.

Once the ecological context of an educational environment is better understood, teachers interested in helping their students learn about and internalize the concepts and practices of sustainability will need additional tools to help students work with their own perceptions of the natural environment. A useful tool for this purpose is the Triadic Theory of Human Mental Functioning and Behavior (Torre 1984, 1987, 1989, 1993, & 1995), which is also grounded in non-linear dynamics. The Triadic Theory is both explanatory and diagnostic and provides a seamless way to think about the myriad of factors that influence each individual learner. The theory posits the interaction of three domains of human thinking and behavior: cognitive, affective/perceptive, and pragmatic, and suggests that a more valid understanding of the ecology of education requires a synthesis of all three types of mental functioning. Triadic Theory, as applied to the ecology of education, claims that each domain has its own way of knowing and verifying information and that educational variables interact chaotically within and among these domains in opposition to each other (Torre, 1995).

The Triadic Theory demonstrates that human thought is fractal in that the self-similar patterns are visible and repeat at different systemic levels in various domains and disciplines. These patterns exist in human beings and human behavior. The Triadic Theory asserts that each of the domains of human thinking and behavior includes the other two. Thinking cognitively requires consideration of the affective and pragmatic. Thinking in an affective way requires consideration of the pragmatic and cognitive. Thinking pragmatically requires consideration of the affective and cognitive. A person who uses this type of thinking productively is able to conjure up the specific proportion of each domain required to deal with problems as they arise. For example, a medical doctor attempting to comfort a mother whose baby has just died would not want to be too cognitive or too pragmatic, but instead emphasize her use of affective thinking, while the same doctor coming upon an auto accident would want to emphasize pragmatic thinking over affective and cognitive processes. Without affective thinking, she would not care about her patients enough to want to help them. Without cognitive thinking, she wouldn't know what must be done to help her patients. Without pragmatic thinking, she could not apply her knowledge to actions that bring about healing and comfort for her patients.

Thought among our hunter-gatherer ancestors would not have been separated into cognitive, affective/perceptive, and pragmatic domains. Instead the three functions would have been totally integrated into one seamless but dynamic process emphasizing one domain over the other two depending upon the task at hand. Our modern day analytic process can be likened to a child wanting to take everything apart but not knowing how to put it back together. Like that child, we need to develop ways of synthesizing our knowledge to offset the damage that analysis alone represents.

No domain of thought in the Triadic Theory works in isolation, and patterns of thought and behavior are not sequential. Instead, the mind is likened to a "massive parallel processor," something that computers are only now just beginning to accomplish. The interaction among the cognitive, affective/perceptive, and pragmatic mental processes takes place in a constant and inseparable flow. Each domain is associated with its own way of knowing and verifying information. Together, the domains interact as a dynamical model for problem solving.

As accurately described by classical science, cognitive processes are analytic, linear, and rational in that they apply logic to observations and reduce the whole to its parts. These processes are the most linear and goal-directed of the three domains. Cognitive processes pursue three tasks: 1) identifying problems; 2) gathering, classifying, assessing, and storing data; and 3) analyzing and synthesizing information.

Affective/perceptive processes emphasize creativity, emotions, and aesthetics as well as perceptivity (intuition, feelings, hunches, and insight). These processes help us identify what would otherwise be intangible knowledge from seemingly imperceptible sources of information. They may also arise when we place our thoughts in context and are able to understand them in relation to the larger background of which they are a part. The tasks of affective/perceptive processes are 1) forecasting probable trajectories of a problem; 2) generating solutions to the problem; and 3) making decisions about the optimal solution to the problem.

Pragmatic processes are experiential and observational. They call for a utilitarian understanding of objects and situations and focus on skills and knowledge that is not taught, discussed, or explained directly. They result from exposure to practices and lifestyles and subconsciously foster specific attitudes and behaviors. The three tasks of pragmatic processes are 1) planning processes, steps, or procedures for a solution to a problem; 2) implementing the tasks described in the planning; and 3) evaluating the solution to a problem based on outcomes and feedback.

Through these ways of knowing, human beings experience the world in different ways and from different beliefs and points of view, a process which often results in opposition, contradiction, or other forms of conflict. The fluctuating energy of our human interaction tends to increase until opposites polarize and split into more and more factions. The corresponding increase in stress can seriously affect the success of problem solving. Instead of allowing opposing forces to come into conflict, we can use this model of mental processes to bring opposing forces together in a working relationship to reconcile the conflict between them.

Although these three ways of knowing interact dynamically and consistently, we often rely more on one way of thinking at the cost of others. Science emphasizes the cognitive, logical, linear mental processes, while the arts value affective/perceptive processes, and business prefers a pragmatic approach. Any one of the three domains of mental functioning can be an activator that motivates an individual to want to achieve something. At the same time, one of the two remaining domains is likely to hold the individual back from achieving it. In many cases, these apparently irreconcilable forces can be brought together via solutions suggested by the third domain of mental functioning. In the case of a sailboat, the activation is the wind against the sail wanting to move the boat somewhere. Restraints are the inertia of the boat and the resistance of the water to the boat's movement. The reconciliation of these forces may be a specialized sail, rudder, and/or helmsperson that puts these forces into a relationship through which the boat sails into the wind, allowing us to sail the boat in the direction we choose.

In a typical human thought pattern, one domain opposes a second domain, while the third domain suggests reconciliation between the other two. This dynamical model of thinking can not only be used to document and reflect upon variables interacting within educational systems, but can also provide a model for reconciling seemingly intractable forces by offering the possibility of win-win solutions. Reconciliation is a way of perceiving, a way of thinking to help solve problems. We teachers need to practice it and teach our students to think, feel, and act in reconciling ways.

For example, we all have an affective understanding of what it feels like to have our own human biological needs addressed. We feel good when we are respected, when there is authentic evidence that we belong to our families, professions, and communities, and when we are appropriately recognized for our competence. Cognitively, we may have some issues about how addressing the human biological needs of our students may impact upon their mastery of disciplinary content. Affectively, however, we have an opportunity to enhance our

teaching of the disciplines by placing it in a context in which our students feel respected, included, and nurtured. Pragmatically, we improve learning by making sure that a hands-on component addresses concrete, everyday applications. If we succeed in this endeavor, we not only have a more productive learning environment in which our students are more likely to learn and internalize the concepts and practices of sustainability, but we also have opportunity to influence additional fractal levels. In thinking pragmatically in an attempt to reconcile our own affective understanding with the cognitive reservations we may have, we most practically begin with the first fractal level of our own well being. How do I as a teacher balance myself so that I have the energy, strength, and caring to accomplish what I want to do with my students? We continue onto the next fractal level in which we consider how best to create an educational environment that addresses our students' biological needs and helps them better understand and internalize the concepts and practices of sustainability. As teachers we can encourage our students to go beyond the second fractal level to a third level, in which they begin to address the human biological needs of each other and of their families, friends, and communities. If there are sufficient numbers of teachers applying this same pragmatic thinking, we collectively have the possibility of experiencing a fourth fractal level in which our students influence others upon which they have direct impact to address our shared biological needs, and as a consequence, better understand and practice sustainability. In so doing, we all practice "paying it forward" to change our perceptions of the world and our ability to live in harmony with our natural environment.

Section 4: Sustainability and the Ecology of Education

"Humanity is no longer an abstract notion; it is a vital reality because now, for the first time, it is threatened with death. Humanity is no longer just an ideal notion, it has become a community of fate and only the conscience of that community can lead it to a community of life." - Edgar Morin⁸

Sustainability for human beings on this planet can be defined as "the potential for long-term maintenance of well being, which in turn depends on the well being of the natural world and the responsible use of natural resources."⁹ During our years as hunter-gathers, we humans lived in greater harmony with the natural world. We understood that we were part of that world and acknowledged that it was part of us. With the advent of agriculture and later on, industrialization, we began to separate ourselves from the natural world and came to believe that we could survive independently of it. In the current century, it could be said that things have progressed to the extent that we humans are now on "life support." Isolating and even barricading ourselves from our natural environment, we live in artificially sustained systems that cannot long survive. When we attempt to do something about our predicament, we apply linear thinking to interact with each environmental component separately and too often do not consider the implications of our actions for the overall environment. We do not perceive our connectedness to each other or to the place in which we live. Only by considering the wholeness of ourselves within the wholeness of our environment will we be able to recognize and act upon sustainable ways of living and surviving.

In order for large numbers of human beings to participate in our own sustainability and that of our planet, we need to learn more about what sustainability is and how to act in sustainable ways as individuals and as members of our concentric communities. But we cannot deal with sustainability without a deep understanding of human nature and the ecological systems in which we live, how to navigate responsibly through our environment, and how to leave the earth better than we found it. To prepare our students to live sustainably, we teachers must also understand the ecology of how people learn, how best to educate our students to act sustainably, and how to encourage them to pass this new behavior onto subsequent generations. But if we can't teach our students to read, how will we teach these even more crucial survival skills? And how can we work with the sociopolitical context of our educational systems in order to implement the changes that will be required?

As teachers, we cannot educate learners about ecology, unless we also understand the ecology of education. In other words, in order to teach students how to act sustainably within our ecological system, we must first understand our current educational system in terms of its own ecology. As we have already indicated, today's schools are artificial environments that do not address the fundamental biological needs we humans acquired over the quarter of a million years we lived in small groups of hunter-gatherers. Furthermore, the interaction of the current educational system with the layers of influence and information that learners are exposed to is hugely complex.

Elinor Ostrom and her colleagues (Ostrom, E., Janssen, M.A., & Anderies, J. M., 2007; Ostrom, 2009) have used principles of nonlinear dynamics to develop a diagnostic multi-tier framework to analyze a number of interacting ecological variables. In one version of this framework, four variables interact to jointly affect and be affected by their resulting outcomes at a particular time and place. These variables are 1) a resource system, 2) resource units generated by the system, 3) the users of the system, and 4) the governance of the system. When we apply this framework to human interaction with nature, the resource system of a fishery generates the resource of fish that is used by corporations that sell fish to consumers that eat them, all three of which (resource, resource unit, and users) are governed by federal, state, and local laws as well as by corporate by-laws and the dynamics of the market. Another example would be the resource system of a lake or reservoir that generates the resource of water that is used by water utilities and the people and businesses that consume the water, all three of which are governed by federal, state, and local water regulations. In each case, the four variables interact in complex ways to influence each other, affect outcomes at a particular place and time, and in turn become influenced by those outcomes.

The national Preparing Future Faculty (PFF)¹⁰ movement in higher education, in which Minnesota PFF (described in Section 3) has been a prominent participant, provides an example of an ecological niche that can be analyzed and better understood using Ostrom's framework. The resource of U.S. graduate schools generates resource units of Ph.D. graduates seeking faculty positions in U.S. colleges and universities. The users of the system -- students, colleges and universities, and the nation -- benefit most when Ph.D. graduates are not only prepared in their disciplines, but have also received preparation to teach and an introduction to the roles faculty are required to fill at different types of colleges and universities. Graduate school programs, however, due to governance by graduate faculty who are rewarded for research rather than teaching, too often do not encourage Ph.D. candidates to prepare themselves for their future roles as teachers and faculty members in community colleges, private colleges, and four-year public institutions. In the 1990s, the Council of Graduate Schools (CGS) and the Association of American Colleges and Universities (AAC&U) used funding from the Pew Charitable Trusts to attract graduate schools to participate in the Preparing Future Faculty program, which offered graduate students coursework in university-level teaching and mentorship by faculty from two and four-year institutions. Many graduate faculty members became persuaded of the need to better prepare their Ph.D. graduates for their future roles, and a number of major universities continue to sustainably offer a PFF program well beyond the end of grant funding. Only by understanding the ecology of graduate education and faculty hiring could PFF program developers grasp the means by which systematic change could occur. To create PFF a number of variables had to come together to interact during a specific time and place to result in a program that has changed the nature of the original educational environment and has become a new and influential variable in the ongoing environment.

Understanding the complexity of how to change educational environments allows us to begin to focus on what to change. Edgar Morin (1999) provides a vision of education for a sustainable future. Morin observes that education can be "blind to the realities of human knowledge, its systems, infirmities, difficulties, and its propensity to error and illusion." To remedy education's tendency to error, learning requires a metacognitive understanding of what knowledge is. For Morin, the fragmented knowledge of separate academic disciplines must be placed in context and understood as a whole. The ultimate goal of learning is to understand the unity and diversity of the human condition. This understanding must take place within a planetary context "to show how all human beings now face the same life and death problems and share the same fate." For Morin, it is as

important to understand our uncertainties as to understand what we are certain about, always leaving room for the unexpected. Mutual understanding on a planetary basis requires comprehension of why and how misunderstanding occurs. Ethics must be understood and practiced by each of us in our own lives, as members of society, and as members of a species.

Morin's vision helps us understand that there are constructive and destructive aspects of human nature and that planning for future sustainability must take both into account. Our hunter-gatherer ancestors lived more in accordance with human biological needs than we do because their environment required them to collaborate in order to survive. Living in nature 24/7, hunter-gatherers had no need to have nature explained to them. They understood their dependency upon nature and generally did not foul their environment with poisons or kill off entire species without thinking of their future needs. Our contemporary environment often encourages the reverse. We can get away with or even be admired for our greed, our laziness, or attitudes of superiority over others. While the authors of this paper agree that people are motivated by fear as well as by their need for growth, autonomy, competence, and relatedness, we choose to emphasize the latter qualities for their value in promoting sustainable behavior over time.

Our ecological approach to changing how we teach children to become sustainable focuses on helping teachers and students develop the capabilities necessary for sustainable behavior. We see these capabilities as qualities that emerge from the interaction of multiple variables within an ecological system. We further believe that the emergence of these qualities in our children will lead to the increased probability of their being able to pass sustainable practices on to future generations. We created the Ecological Planning Framework for Teaching Sustainability in Figure 6 based on one of several frameworks developed by the Center for Education and Communication (Brookline, MA).

Figure 6: An Ecological Planning Framework for Teaching Sustainability

Purpose:

To teach our students how to interact with the environment in ways that bring about well being for humans and the natural world so that we can live sustainably into the future.

Outcomes:

- a. Ways of addressing human biological needs in families, schools, and communities.
- b. An integrated, experiential, and multidisciplinary approach to sustainability in our schools.
- c. An ecological approach to education by teachers, administrators, and decision makers.

Processes:

- a. Focus teacher development on addressing the biological needs of students by recognizing these behaviors, practicing them as teachers, and encouraging students to do the same.
- b. Create integrated, experiential, and multidisciplinary approaches and activities that simultaneously recognize student biological needs and help them understand and apply principles of sustainability.
- c. Develop global strategies of education and find ways of adapting them to specific local needs.

Capabilities:

- a. Ability to address effectively the biological needs of students and help them develop these capabilities themselves.
- b. Ability to create integrated, experiential, and multidisciplinary approaches and activities that recognize biological needs and teach sustainability.
- c. Ability to develop global strategies of education and/or adapt global strategies to local needs.

In each of the three elements (outcomes, processes, and capabilities) in the framework above, there are three interactive variables: a) human biological needs, b) integrated, experiential, and multidisciplinary approaches and activities, and c) global strategies of education applied locally. These variables can be tracked across our framework from outcome to process to capability, all in service to our overall purpose. We believe that it is through the interaction of these variables that the desired quality of sustainability for our future can emerge.

One school in which many of these outcomes are met is John C. Daniels School of International Communication in New Haven, Connecticut. This is a highly successful school in terms of standardized test scores as well as other measures. When asked, what is it that makes you so successful at Daniels, school principal Gina Wells (personal communication 5-21-10) replied:

I get to know my kids. As an administrator, if you have your thumb on the pulse of the school, I think that you can really make changes. What I am all about is getting to know the kids, and personalize as much as I can, and when you do that, then of course, you know the families too. Families are not an entity of their own. They come with a whole lot of baggage, or a whole lot of "great parcels," as I call them.

We have lost [the ability to respect, recognize, and trust each other] over the years. I think it has happened in everything, but it happened in families when the mom had to go out and work. There was a whole breakdown all along the way. We just need to reconnect again. All those old values that our grandmother taught us when we were "one big happy family," we don't have any more. That's what I try to do in my school. I try to create a family around me. I think if every school could do that, we'd all perform better.

For example, today out in the hallway, I had about six kids who really had a problem at lunch. Nobody else wanted to take the time to deal with it, but I just had to find out what pushed their buttons to get them to that point. The whole village has to do it. [It's] just getting to know what makes these kids tick. They are all individuals. What makes this kid do a good job on a paper, and this other kid not? But maybe the other kid could have done a better job if you had done something differently.

In Gina Wells' school we see a concrete application of this paper's assertions. John C. Daniels School is among the highest performing schools in Connecticut. The school has taken global solutions and applied them locally to great success. Through the school's dual language program "all children are instructed in Spanish and English with the goal of becoming bilingual and bi-literate in both languages by the end of eighth grade" and the school's focus is on "the development of the whole child: intellectually, physically, emotionally, and socially."¹¹ At John C. Daniels School, students are respected, recognized, and trusted. The principal's desire to create family around her at the school is a recreation of the hunter-gatherer band, with intimate, face-to-face communication, where teachers better understand each student by knowing their family. The principal is kept informed of issues of concern to families and their children. Because of the extra attention given to their concerns, students feel they belong, are liked, and are surrounded by people they can trust. By helping students understand how to solve their own problems, they begin to feel competent. By being trusted, students begin to feel they are reliable. When the principal takes the time before taking action to find out what is happening and how each student experiences it, students feel they are surrounded by trustworthy, competent people.

Addressing the biological needs of our students assists them in developing strong social ties and a life of well being. According to Ryan, Huta, and Deci (2008), these qualities lead to the pursuit of personal growth, relationships, community, and health for their own sake, as well as behavior that emphasizes competence, relatedness, autonomy, volition, consensus, and self-awareness. Brown and Kasser (2005) further assert that

subjective well being has been shown to correlate with more ecologically responsible behavior, stronger intrinsic values, and higher degrees of mindfulness; and we might add, vice versa.

Additional relevant research suggests that learning occurs most effectively in dynamic, fluid environments that empower and emancipate individuals and their communities (Reason & Bradbury, 2006). Learning about learning reduces fear and develops hope and courage (Pyrch, 2007). Self-reflection in a collaborative context brings about collective and individual empowerment and emancipation (Boog, 2003).

Learning about sustainability is enhanced when people identify with the place in which they live (Gustafson, 2001; Manzo, 2003, 2005) and is more successful when influences of commercialization, consumption, and materialism are minimized (Hacking, Barratt, & Scott, 2007; Alparone & Rissotto, 2001; Spencer & Woolley 2000). We also know that sustainable activities at the local level are best achieved by bringing together stakeholders with relevant expertise to engage in creative problem-solving (Cash, Clark, Alcock, Dickson, et al., 2003). Finally, because humans are also part of nature in that we collectively self-organize around specific problems that confront our communities in order to create networks that correspond to those that can be seen in nature (Losada & Heaphy, 2004; Frederickson & Losada, 2005). All of these findings can be put to work in our classrooms to encourage the learning and practice of sustainability.

Another New Haven school, The Sound School Regional Vocational Aquaculture Center¹², demonstrates how students can learn sustainable ways to interact with the ecology of the ocean. The Sound School strives "for authentic learning through powerful experiences and powerful teaching. At [the school's] command is a learning environment as small as a ruler, or as wide as the ocean." The school sees their location on the shore of Long Island Sound and their focus on vocational aquaculture and agriculture curricula as "powerful tools to capture student interest and motivation, ensuring student fluency, and therefore, student achievement." "The knowledge and values inherent in a love for the marine environment, America's agricultural heritage, and New Haven's maritime tradition are transmitted to students consistently." Most of the important activities at The Sound School, such as studies of environmental effects on animals in Long Island Sound, are being carried out by students. Graduates of The Sound School learn about their roles as stewards of the earth and acquire a working knowledge of the tools of marine and/or agricultural commerce, and marine and/or terrestrial ecology.

The teacher candidates in Carlos' class often car pool to The Sound School to be introduced to its campus by its principal Steven Pynn. One year a student came late and got lost looking for the tour. The lost student was not stopped by security personnel, but instead was welcomed and guided by Sound School students to the place he needed to be. The teacher candidate was impressed with the level and spontaneity of hospitality at the Sound School, something unusual for a high school in these security-conscious days. He later commented on the trust among the people at the school, and that he had observed a higher level of respect for students and recognition of their trustworthiness.

The Sound School provides the very best personnel to help students learn. When the teacher candidates on the tour asked the principal, "How do I get to teach in this place?" he responded, "Very difficult. Your first hurdle is me. If I don't think you can provide what these students need, you don't go on. You have got to have skills in two main areas, the discipline itself: math, English, or whatever you are prepared in, but secondly how to apply your discipline to aquaculture, so that you are actually practicing it in the content of the ocean. Very few English teachers are able to apply English to the ocean: they may fish but they don't understand fishing as a process."

Fritjof Capra (1982) tells us that it all has to change at once. We can't take one piece and fix that. Pieces in isolation are no longer connected to what they are part of. It is like the following story¹³:

There was once a man who in the morning complemented his wife on the beauty and shine of her hair. An hour later as he was about to eat the soup his wife had made for lunch, he said, "The soup looks good." But then he found a strand of hair in it. "What's this?" he said, "Dirty hair in my soup!" His wife replied, "This morning you said my hair was beautiful and just now you said the soup looked good. Now eat it! It should be doubly beautiful."

Once the hair was separated from his wife's head, it of itself no longer interacted with the other hairs to result in the emergent qualities of beauty and shine. Similarly, we cannot tinker with one variable and expect to achieve our outcomes. We must change it all. In New Haven, where Carlos is President of the Board of Education, the entire school district has made the commitment to address the achievement gap that exists between dominant and subordinate ethnic groups. The project launched with an all out effort to deal simultaneously with parent feedback, curriculum change, teacher evaluation, administrator evaluation, and school board evaluation. All curricular and process changes will be part of the same effort. To be able to go on to the university after graduation, New Haven students must be prepared academically and emotionally. Because the students will be prepared, the district has committed to find the money the students will need to go to college, even to the University of Connecticut, the highest priced public university in the state. Instead of "reform," New Haven calls this effort "change," and it might be fair to refer to it as a "transformation."

The ecology of education provides solutions in evolution. As the conditions of human life change, the values that guide us will also change. Ecological thinking can help guide these changes in positive, peaceful, and sustainable ways. For example, each time we solve a problem, new problems are created. For example, when New Haven schools dramatically decreased absenteeism, and previously absent students came back to school, there were not enough seats for them. Similar to most school districts, New Haven schools had predicted how many students would actually be there on any given day and cut down on equipment accordingly. A new school, that had just been reconstructed to be bigger than the original building, was not big enough. But the district would far rather have the second set of problems than the first.

As we said earlier, we believe the goals of education are to help us understand who we are, comprehend the world we live in, learn to navigate our world, and leave it a little better than we found it. Preparing our students to achieve sustainability means having a world that can continue through the generations. If our teaching and sustainability practices are ecologically sound, our progeny can live on without threat to their survival.

Section 5: The Current Crisis

"Education is too important to be left solely to educators." - Francis Keppel, U.S. Commissioner of Education (1962–1965)¹⁴

Our current educational crisis is real, but it is a crisis of perception. Where have we gone wrong? How are we not seeing the reality of our situation and what needs to be done to address it? We believe the current crisis came about because we humans have changed our environment in ways that contradict our own human nature. We cannot educate effectively using strategies and techniques that go against the grain of those we are trying to educate. Our biological heritage causes us to do poorly in large, bureaucratic hierarchies with one-way communication, lack of democratic process, and dehumanizing factory or business metaphors used to organize and manage students and their schools.

Larry Olds, popular education expert and editor of *Popular Education News*¹⁵ (personal communication 5-13-10) suggests that students need to get back to discovering knowledge for themselves rather than only applying knowledge gleaned from others. Olds cites Ralph Tyler (1949) as one of the originators of our most recent departure from viewing learning as a process of discovery. Tyler's curriculum theory reduced teaching

to four steps: 1) Figure out your goals; 2) Create your activities; 3) Carry out your activities; 4) Evaluate the success of your activities according to your goals. This pattern of thinking is so embedded in our modern day culture that it seems second nature. Everyone participates in this way of thinking; it is the way we think about what we do, but it also has a political history that reflects our assumptions about the nature of knowledge. In our common way of thought, the student is an object to be manipulated and controlled. The only action that is valued is one that is goal-directed. No other action type, such as those of creation or spontaneity, is considered.

We teach in mechanistic ways, separating education from life, no longer cognizant that we are part of the natural world. We may attempt to "reform" our schools, but we do so in mechanical ways, like gauging success in terms of test scores. Then we are surprised when students experience our efforts at school reform as something more akin to being in "reform school." With such mechanistic approaches to teaching, how can we help students acquire the skills necessary to live sustainably in our world? Instead of placing the burden entirely upon schools, we now understand that it takes a village, a city, a country, and the planet to educate our children. School needs to be re-conceptualized in terms of what is possible for schools to actually do. Even if we teach more effectively, in only six hours a day (and with lunch, interruptions, and recess, five or fewer hours per day), how can we teach everything that students are expected to know? If we are really honest about it, we must admit that the learning our children require to create a sustainable world is not taking place and cannot take place in the schools alone.

The world is so complex today that education can no longer focus on conveying information. Instead, we must help our students learn about learning. They learn continuously throughout their waking hours and most of these hours are not spent in school. The internet, cell phones, and other media dominate their lives. We need to teach our children how to distinguish among the varying levels of relevance and truthfulness in the avalanche of information they receive daily. To quote E.O. Wilson, "We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely."¹⁶ These are the skills our students will need to navigate the continuously evolving process of diagnoses and strategies for achieving sustainability.

A major symptom of the dysfunction of our schools is the recent escalation of school violence. VanderVen and Torre (2000) describe these new levels of violence.

School personnel encounter not only defiant, unruly, bullying children and youth, but also—and gravely ominous—youngsters who bring weapons to school, brandish them, and use them. Among the recognized forms of in-school violence are shootings of both students and teachers; stabbings, burnings, wanton destruction and trashing of property, and more and more advanced forms of fighting and bullying including shake-downs. Girls increasingly are victimized—by boys who make sexual advances, sometimes violent, and by each other.

When we consider school violence from the point of view of the ecology of education, we see that a great many variables interact to create and define school violence and that any solution to the problem must consider its complexity and unpredictability. VanderVen and Torre (*ibid.*) describe our societal search for the "quick fix" as "obviously 'linear'" and suggest that "violence itself has been viewed as a singular, rather than multiply determined, phenomenon, with multiple causes, multiple forms of manifestation, and varying forms of expression and severity." The authors suggest mediations to school violence that 1) Are systemic in that they touch the entire societal system of students, families, and community; 2) Consider and address the complexity of issues related to school violence; and 3) Recognize and comprehensively address interacting connections between various levels of the hierarchical system of students, teachers, schools, and educational practices.

Another major symptom of the dysfunction of our schools is the "achievement gap" in which socio-economically disadvantaged students tend to lag behind their peers in learning as measured by test scores. The current way of resolving the problem is to focus on improving test scores. While test scores have something to say about student learning, our society's singular focus on them represents the limited world view of linear thinking. Looking at test scores through the lens of the ecology of education, we see that innumerable variables interact with each other and with their outcomes to result in current levels of learning and that test scores represent only one of many measurements that can tell us what is actually going on in our schools.

The Davis Street 21st Century Magnet School in New Haven has made inroads on the achievement gap by thinking about the problem in more nonlinear ways (Bass, 2009). Students, teachers, and parents worked together to find new strategies for learning. At Davis Street School, "62.6 percent of the school's African-American fifth-graders made goal on the most recent exams, slightly higher than the overall state average, almost double the average for African-Americans." This feat was accomplished "through involving parents, staying on top of the data, and pushing students one-on-one to overcome obstacles." Teachers discovered that one reason students lagged behind was not wanting to risk being wrong. To counteract this fear, teachers stopped allowing other students to laugh at the mistakes of their peers, pointed out their own mistakes on the blackboard, and worked to create a safe space for children to participate in class without fear of getting the wrong answers. Teachers divided their classes into work clusters, grouping students with similar challenges and strengths, letting each group work independently while the teacher roams to help individual students. At the same time, teachers brought parents into the loop, letting them know whether or not their children completed homework assignments and asking for their signatures to indicate they had received the information. Teachers followed up by phone when children were not doing homework and not completing the communication loop with their parents, encouraging parents to put the needs of their children higher on their list of priorities. Parents and other relatives were urged to become more active in the school. Students were also encouraged to begin attending after-school programs for co-curricular activities and additional help with homework. As one previously lagging student said, "They're more like a family" in finding ways to engage students in their learning rather than punish them for being caught up in situations beyond their control.

We believe that to resolve the problems of school violence and the achievement gap, as well as to teach sustainability in the most effective way, our society needs to better prepare teachers to address the human biological needs of students in nonlinear ways. The complexity of this endeavor requires teacher educators to consider how each interacting system impacts on others. For example, for teacher educators to help future teachers think about the biological needs of their students, they must first "walk their talk" by observing the human biological needs of their teacher candidates. By practicing what we preach, we teach by example, a far more effective method than prescription alone. Then for teacher candidates to understand their own biological needs and those of their future students, they will require a curriculum of reflection and introspection as well as psychological study of human thinking and behavior. To do this, emphasis must be placed on affective/perceptive and pragmatic mental functioning as well as cognitive processes.

Goleman (1994) recommends curricula that assist students in understanding and working with their emotions. An example is The Self Science Curriculum that includes work on components such as self-awareness, personal decision-making, managing feelings, handling stress, and empathy. Self science encourages collaboration over competition and reconciliation over conflict. Goleman indicates that this program and others like it benefit students by helping them develop competence in emotional self-awareness, managing emotions, harnessing emotions productively, developing empathy, and handling relationships. Affective/perceptive skills cannot be studied or understood in isolation. Emotional competencies interact with each other and with the other two domains of cognition and pragmatics. The curriculum will need to be holistic and integrated, using story, play, and hands-on experience, to help students learn and transform their thinking and behavior. Sample ideas for such a renewed curriculum appear in Figure 7.

Figure 7: Ideas for Renewing Curricula for Teacher Education

- Imagine how hunter-gatherer education addressed human biological needs and encouraged each generation to do the same for the next generation. Apply these ideas to the modern day classroom.
- Use the research on multiple intelligences to create a curriculum that draws on all three domains of human thinking and behavior: cognitive, affective/perceptive, and pragmatic.
- Create a rubric describing ideal behaviors of a teacher addressing the biological needs of students.
- Revamp class schedules so that one teacher works with each group of students for two to three weeks, with students taking one class at a time, full time, freeing up the teacher and students to do whatever is needed to deal with the course topic.
- Use team teaching across disciplines to break down disciplinary silos and begin to teach in an integrative way.
- Consider how the use of story (storytelling, print, and multimedia) can create and sustain interest, encourage insight, and provide relevance.
- Model learning after the "Mission Impossible"¹⁷ team by structuring small group learning teams with each group member bringing their unique talents to the team's learning goals. To succeed, the group must take advantage of everyone's abilities.
- Ask family and community about the strengths of each student. They may have noticed competencies teachers are unaware of. Put these talents to work in school. Make sure that students are aware of real competencies that others value in them.
- Encourage the practice of reflection and meta-cognition as a part of all activities. Learning to learn includes understanding of what one has learned, how and why one learned it, and what can be improved the next time around.
- Create an atmosphere of trust and cooperation in the classroom in which each person is respected and valued for their unique areas of competence.

In contemplating our current crisis in education, we ask the question. Who is accountable? Torre and Voyce (2007) assert that we all share accountability for the learning of our children. They explain that our predominant metaphor for explaining the accountability of systems has come from the world of manufacturing. Using this metaphor, schools are factories that take the raw material of children to produce the product of educated students. This metaphor does not take into account the complexity of students, teachers, schools, and educational processes themselves as interacting nonlinear systems. Furthermore, if students are our products, then we have to start with the best possible raw material, which means that we cannot accept all students into our schools.

In contrast, Torre and Voyce (*ibid.*) compare our current crisis in education to that of a gardener whose livelihood depends on cultivating healthy, thriving plants. When the plants suffer through a drought, struggle in infertile soil, fight off pests and disease, or are choked by weeds, the gardener's role is to provide the plants with whatever they need so that they may survive and become productive. In the same way, schools must attend to the needs of students to ensure that they survive and thrive. The gardener and the teacher are not the only ones responsible. Our government, our communities, and each of us as citizens must share accountability for the future of our children.

In hunter-gatherer culture, the concept of shared accountability was deeply internalized to the point where no one would even question it. It was a way of life. It was assumed that everyone knew and operated according to this principle. Each group had to live this way or everyone in the group would sink together. For our global village to survive, we must recover our shared accountability for the human species. If we really believe that it takes a village to raise a child, why is it that only teachers live in that village?

Section 6: Exemplary Practices

"Walker, there is no road. We make the road as we walk." - Antonio Machado¹⁸

To paraphrase Bill Clinton¹⁹, isn't it interesting that someone has solved every problem in education somewhere, but we can't seem to solve all of these problems everywhere. We do not have to look far for solutions to our current crisis. There is no shortage of solutions out there. What there is a shortage of is knowledge and connectivity between people who have come up with solutions, acted upon them, and are ready to share their experience with others. The fact that our crisis is one of perception means that many of us do not yet see the problem and are not yet looking for solutions to it. When we humans finally know what is important for us to survive and thrive, we will do whatever it takes, dedicate whatever resources are required, and go to the ends of the earth to make sure it happens.

The problems seem overwhelming because each of us feels like we are taking on the world. For this reason, those of us who experiment with solutions must find and communicate with others on similar paths to join forces and share resources. One person cannot sustain these efforts by him or herself. If it takes a trillion dollars a year to solve our problems, each of us could probably sustain the effort for a billionth of a second. When more and more of us contribute, the effort becomes sustainable. Each of the projects we come up with cannot solve all of the issues. Interconnectedness is required to sustain the three-dimensional web of our combined efforts.

We cannot wait until we have the perfect solution, nor can we find the perfect guru to guide us on our way, but because we are making the road as we walk, we can look for people who have walked the road before us. Once we have received guidance from another who is farther along the path, we need to reach out to the next and the next, until there is no one else to help us further. At that point, we can trust we have learned enough from others to be our own guides, and in the process become guides for others. It is also the case that simply having someone describe the path to us does not get us there. We have to walk the path ourselves and actually do what we know needs to be done. There is a surplus of people who know what to do and tell others what to do, but don't do it themselves.

One of S. N. Goenka's students once asked, "You want us to become enlightened, but are you yourself enlightened or is this the blind leading the blind?" Goenka replied, "It's not the point whether I am or am not totally enlightened. I have walked many more steps along this path than you have. Therefore, I can lead you further along than you are now. Whether you become totally enlightened is up to you. I am a worthy guide because I know more about the path than you do."

As we walk the road toward change, there is a need for balance. In the *Tao Te Ching*, Lao Tsu reminds us, "The more laws and restrictions there are, the poorer people become. The sharper men's weapons, the more trouble in the land. The more ingenious and clever men are, the more strange things happen. The more rules and regulations, the more thieves and robbers." Human beings need balance to limit the effects of our own self-regulation. The more a person tries to control people, the more others want to escape from the influence of that person. The more we succeed in unbalancing something, the more grotesque the reaction to actions may become.

Leslie Gray, a Native American psychologist and shaman, relates that

The Native American model [of health] is a dynamic one: the idea is *not* to eliminate the "bad" and replace it with the "good" but rather to keep the balance. . . .The idea is to include the Totality. How can you have the concentric without the eccentric? How can you have a wave without both trough and crest? What would light possibly shine out of, if not darkness?" It is not that our past way of doing

things was entirely good or that our present way is entirely bad but that we have lost the balance between who we have been and who we may be becoming (Platek, 2009, pp. 10-11).

The psychological researcher Barbara Fredrickson, talks about the importance of balancing the positive emotions -- which we consider equivalent to our notion of human biological needs -- with negativity.

Positive emotions tell us not just what the body needs but what we need mentally and emotionally and what our future selves might need. They help broaden our minds and our outlook and build our resources down the road. . . . When people increase their daily diet of positive emotions, they find more meaning and purpose in their lives (Winter, 2009, p. 7).

Fredrickson reports on a study of sixty business teams doing strategic planning in which fellow researcher Marcial Losada uses mathematical methods that match those from nonlinear dynamics with the following results.

[The] high-performing teams had about a six-to-one ratio of positive to negative statements, whereas the low-performing teams had a ratio of less than one to one, meaning that more than half of what was said was negative. People on the high-performing teams had an even balance between asking questions and advocating their own points of view, and also an equal measure of focusing outward and focusing within the group. The low-performing teams had asked almost no questions and almost never focused outside the group. They exhibited a self-absorbed advocacy: nobody was listening to each other - they were all just waiting to talk. . . . You could see that the two groups, high- and low-performing, were not just different in degree, they were different in kind. . . . Using the Lorenz equations, we were able to algebraically predict that a ratio of three positive events to one negative event should be the tipping point where things become chaotic -- in a good sense -- and a medium-performing team becomes a high-performing one I tested that ratio against my own data in one study after another. Each time I found support for the idea that the three-to-one ratio is a tipping point. . . .

The discovery definitely changed the way I thought about parenting. When your kids are young, your reactions help shape how they perceive their experiences - whether they're going to feel good or bad about what just happened. You're the sculptor of their emotional lives. We tend to tell toddlers, 'No, no, no,' all the time. My work made me think there needs to be more playfulness in my parenting, more emphasis on stepping back and following the child's interest. On some level, I think parents know this, but the three-to-one ratio provides a yardstick against which I can assess how a day went. It motivates me to make sure that the negativity I send my sons' way is necessary and in proper proportion with the positivity I offer them. I want to be sure my sons have an opportunity to express whatever they're feeling and to follow their interests. . . . The people who do best in life don't have zero negative emotions. In the wake of traumas and difficulties, the people who are most resilient have a complex emotional reaction in which they're able to hold the negative and the positive side by side (Winter, 2009, p. 8).

We assert that most pedagogically sound efforts at transforming education take us back to the future to a more contemporary form of our original hunter-gatherer ways. As examples, we will examine the educational practices of a small village in Italy named Reggio Emilia, the famous Summerhill School in England, the use of storytelling and play in education, the importance of hands-on experience, and Comer Process developed at Yale University.

Reggio Emilia schools,²⁰ now found throughout the world feature an emergent curriculum that builds on the interests of children. Reggio Emilia teachers work in teams with parent support to develop the projects or adventures that emerge from student interests. The teacher's role is to be a learner along with his or her

students. These schools emphasize multiple intelligences, collaborative group work, and respect for our environment and ourselves. Student work is documented along with the words they use to discuss what they are doing, thinking, and feeling, as a means of understanding and guiding the learning process.

School buildings become a part of the Reggio Emilia process by connecting classrooms to nature. For example, the Reggio Emilia school in Barranquilla, Colombia, features circular classrooms with windows all around from which students can see the surrounding trees and mountains. The classroom environment is intended to be one of joy and playfulness. Teachers encourage cooperation, dramatic play, and activities that mingle students from many different classrooms.

The Summerhill School in England²¹, which has also been replicated throughout the world, is still thought of as the most radical of the alternative schools. There are no grade levels -- students of all ages and abilities learn together. Summerhill teachers believe strongly in democracy. Students are part of all decisions at the school. Adults serve as guides and do not participate in the decision-making. These practices correspond to hunter-gatherer practices of respect, inclusion, participation by consensus, and being kept in the loop. Students learn democracy by practicing it. For example, a recent BBC film on Summerhill²² depicted a father who placed his troubled son at the school because he didn't know what else to do with him. In the drama, the son beats up one student and steals money from another. In response the students form a court to discover the truth about what happened and decide what to do about it. Instead of merely telling students about democracy, but at the same time, forcing them to learn within an autocratic system, as most schools do, Summerhill guides students in learning about democracy and then trusts them to live and act in a democratic manner. The school describes its understanding of human biological needs as follows:

The Summerhill School was founded in 1921 at a time when the rights of individuals were less respected than they are today. Children were beaten in most homes at some time or another and discipline was the key work in child rearing. Through its self-government and freedom it has struggled for more than eighty years against pressures to conform, in order to give children the right to decide for themselves. The school is now a thriving democratic community, showing that children learn to be self-confident, tolerant and considerate when they are given space to be themselves.

Storytelling is another means of revitalizing the classroom in ways that emulate hunter-gather exchange around campfires. The anthropologist Gregory Bateson argues that we are "storied people" and has one of the characters in his *Metatalk* say,

Even when I tell stories out of my experience, it's not my own history I'm talking about. The stories are about something else. . . . Does a story have to have *really happened* in order . . . to communicate a truth about relationships, or in order to exemplify an idea? Most of the really important stories aren't about things that really happened -- they are true in the present, not in the past.²³

Stories make accessible complex ideas that would take much longer to access cognitively. For example, the following story of the monkey and the fish could be used to teach elementary school students that what is good for you may not be good for others. Or it could be used to help teacher candidates understand the folly of assessing all students with one standardized test regardless of their language abilities or socioeconomic status.

Once there was a storm that swept a monkey into the current of a river. The monkey was batted back and forth against rocks and trees as the swift current carried him down the river. Finally, the monkey saw a tree branch that was higher than the level of the water. He aimed for the branch as he approached the tree, grabbed it, and pulled himself out of the water. Gasping with relief, he shouted, "I'm saved!" Suddenly in the distance, he saw a fish in the circumstances from which he had just saved himself. As the fish passed underneath the branch, he reached out and pulled it from the water.

"What are you doing?" cried the fish. "I can't breathe!" The monkey scratched his head. He couldn't understand why the fish was not grateful. The perfect solution for the monkey was the wrong solution for the fish.

In his 2005 memoir *Teacher Man*, Frank McCourt came to understand that telling stories to his students was the best thing he could have done. The students thought he was off task, but he was teaching and they were learning.

I'm twenty-seven years old, a new teacher, dipping into my past to satisfy these American teenagers, to keep them quiet and in their seats. I never thought my past would be so useful. Why would anyone want to know about my miserable life? Then I realize this is about what my father did when he told us stories by the fire. He told us about men called seanachies who traveled the country telling hundreds of stories they carried in their heads. . . .

I argue with myself, You're telling stories and you're supposed to be teaching.

I am teaching. Storytelling is teaching.

Storytelling is a waste of time.

I can't help it. I'm not good at lecturing.

You're a fraud. You're cheating our children.

They don't seem to think so.

The poor kids don't know.

I'm a teacher in an American school telling stories of my childhood days in Ireland. It's a routine that softens them up in the unlikely event that I might teach them something solid from the curriculum.

Like storytelling, play as a part of the educational process that has been underrated and misunderstood. Fromberg and Bergen (2006) document seven characteristics of play.

- Play is symbolic, representing reality as as-if or what-if.
- Play is meaningful, connecting and relating experiences.
- Play is active with children doing things including imagining.
- Play is pleasurable, even when the activities are serious.
- Play is voluntary and intrinsically motivated, regardless of what the motives are.
- Play is implicitly or explicitly rule-governed.
- Play is episodic with spontaneously emerging and shifting goals.

Play is a nonlinear activity. It is unpredictable how things will pan out, but something always happens and emerges along the way. It may be wonderful or terrible. Play is each child's work. When parents come home tired from working all day, and someone wants him or her to do something, the parent often resists by stressing that he or she has worked all day and needs to rest. Children work all day at play, and then we adults want them to clean up their rooms. Play is what children are supposed to do. The better they play, the better they understand the world and the better they are prepared for formal education. We do not need to teach children how to play. They know how. But we can help develop ways of playing, like drama.

As a Yale undergraduate, Michael Miller created PlayScape, working with the Yale Children's Theater to teach kids about drama by actually setting up a play, but without telling them what the parts of a play are. This is teaching by doing. Dialogue between teachers and students in PlayScape (Miller 1991) might go it does in Figure 8.

Figure 8: Sample PlayScape Dialog

Students	Teacher
"We want to put on a play."	"What do you want to put on a play about?"
"Dinosaurs helping each other."	"OK, who is in the play?"
"Two dinosaurs and an astronaut."	"OK, so what happens? How do the dinosaurs help each other?"
"One helps the other one build a house."	"Ok, let's start playing."

(The students start playing and eventually run out of ideas.)

Students	Teacher
"We're stuck."	"OK, the astronaut is on the moon and the dinosaurs are in the jungle, how do we get them together?"
"We could build a rocket!"	"OK. Let's do it!"

The Riley School²⁴ in Rockport, Maine, founded in 1972, has long advocated the importance of play. Riley, like Summerhill, is ungraded, and has a teacher to student ratio of one to eight. School founder, Glenna Plaisted, describes the school's philosophy. "Children are born with curiosity, a fervent, innate desire to learn. We honor that at Riley. Our boys and girls learn through their own initiative, their own action. Learning, like life, is a process, not a result. Education is a process of child discovery. It's not the teacher giving facts to the child, but the child's own deep involvement. What we call play, the children call work." Skye Hirst of the Autogonomics Institute in Maine²⁵ comments, "Thirty years ago her philosophy must have been seen as more than controversial. It must have been seen as outrageous nonsense. But Glenna was an astute observer. Today the new science of biophysics supports her philosophy."

Children's play is more of an implicit activity than an explicit one, yet there is a need to balance the two approaches. When Carlos was a graduate student at Harvard, his advisor, Gerald Lesser, was the president of the Children's Television Workshop, which produced Sesame Street and The Electric Company. Lesser's graduate students were put to work interviewing children who represented the audience for Sesame Street. One of Carlos' classmates was perturbed to find that most of the children being interviewed said they liked Mr Rogers better than Sesame Street. Finally, when one more interviewee said he preferred Mr. Rogers, the grad student burst out, "Why do you like that boring old man?" The student's shoulders caved in and he sunk in his chair, "Because he doesn't try to teach us anything."

Sesame Street is explicit education, somewhat akin to linear thinking. Mr. Rogers was implicit education, more in tune with nonlinear thinking. Mr. Rogers' dialog with children went something like this: Hello, boys and girls, today we are going to take the trolley to visit the king. Oh, excuse me, boys and girls, I forgot to tie my shoes." And Mr. Rogers would continue to talk about what they were going to do today while tying his shoes. The children would watch him tie his shoes while he is talking. They knew they didn't know how to tie their shoes and were interested in how Mr. Rogers did it. Sesame Street might teach shoe-tying in a more mechanical way with verbal instructions. "First, you take the two ends of the laces and cross one over the other." And so on. Children watching shoe-tying instructions on Sesame Street might respond something like this: "You're trying to make me do something I don't want to do. It isn't fun and I don't like it." Explicit education like that of Sesame Street can be more easily assessed later on, but it doesn't go in very deeply and there is lots of resistance to it. Implicit education goes in at the deepest level. For example, culture is taught implicitly. You will never forget how to be a Yugoslavian or a Christian or a Democrat or a Republican. It goes in at the deepest level, but it also goes in as the unexamined truth. "I am a true believer and the rest of you are heretics." "My culture is the one true culture, the rest of you are colorful and interesting." But there is not an either/or choice between implicit and explicit education. Both are needed. We just have to find an appropriate balance between the two.

Another way to educate in a nonlinear manner is through hands-on experience. Henri Poincaré, the original discoverer of nonlinear dynamics, reminds us that it is better to demonstrate things than talk about them. "Experience is the unique source of truth: it alone may teach us something new; it alone may give us certainty. These are two points which no-one can contest."²⁶ Two examples of hands-on experience are the use of manipulatives in math and science and taking students out into the world to learn by doing.

Manipulatives are physical objects used to teach more effectively. The vendor Academic Superstore²⁷ lists a variety of manipulatives ranging from alphabet and phonics bean bags for spelling and reading to bags of shapes for geometry to an electronic lab for building ten different types of circuits. Manipulatives for teaching astronomy and geography might include a physical model of the solar system with a globe representing the earth and a moon orbiting around it. Albert Einstein was particularly fond of what have come to be called manipulatives. He once admitted he could not understand his own insights without a model of wax and string and also said, "I never teach my pupils. I only attempt to provide the conditions in which they learn."²⁸ (Einstein's way of facilitating learning, by the way, is an excellent example of self-organization.)

There are any number of examples of hands-on teaching focusing on the natural environment in what are known as "living classrooms."²⁹ In Maryland, students can choose between a Baltimore program on urban gardening, a Chesapeake Bay program on shipboard education and environmental outreach, and a Baltimore Inner Harbor program on exploring arts and crafts. The urban gardening program takes place year round, as well as in the summer, and offers "activities such as cooking, gardening, creative arts and movement, and entrepreneurial projects to help increase academic performance in reading and math and improve student behavior."³⁰ The shipboard education program serves "students from a variety of backgrounds and economic means and range[s] in length from one-day expeditions for school and youth groups to extended shipboard and land/sea programs. . . . Leadership and teamwork are key objectives as students work together to raise and lower sails, trawl for marine life, perform scientific tests, and explore the commerce, history, natural resources, and ecosystems of the Chesapeake Bay."³¹ Students in the Baltimore Inner Harbor program participate in "activities that include arts and crafts and use of digital pictures, model paddle boat construction and racing, outdoor games, a banner project, field trip to the MD Council for Special Equestrians (therapeutic horseback riding), sand art, sailing aboard skipjack Minnie V. and pungy schooner Lady Maryland, mosaic frame mirror art, a gardening project, and a field trip to the National Aquarium in Baltimore."³²

A final example of teaching in nonlinear ways is the Comer method, developed at Yale University by James Comer, whose book on *No Child Left Behind* (Comer 2004) states, "Good relationships among and between the people that influence the quality of child life, largely home and school, make good child and adolescent rearing and development possible. Good relationships make student, adult, and organizational development possible, which in turn makes a strong academic focus possible." Comer's website³³ describes the Comer Process as follows:

Like the operating system of a computer that allows the software to do its specialized work, the Comer Process provides the organizational, management and communication framework for planning and managing all the activities of the school based on the developmental needs of its students. When fully implemented, the process brings a positive school and classroom climate, stability, and an instructional focus that supports all of the school's curriculum and renewal efforts.

The Comer Process employs three types of teams of teachers, students, parents, and administrators that operate under conditions of no-fault problem-solving, consensus decision-making, and collaboration to support nine developmental pathways as shown in Figure 9. The majority of these pathways back up the need to support human biological needs in fractal patterns using teams much like the bands of our hunter-gatherer ancestors, in which every individual is valued for his or her unique competencies.

Figure 9: Comer Method Developmental Pathways³⁴

The Social Pathway	Enhancing healthy interpersonal relationships through student work in complex, structured group activities to be able to participate effectively in a variety of social contexts.
The Ethical Pathway	Helping students learn to reason, understand ethical principles, and use them to make decisions about their own actions.
The Physical Pathway	Developing hand-eye coordination, physical dexterity, visual acuity, and auditory perception.
The Cognitive Pathway	Learning to think, plan, solve problems, and accomplish goals for use in addressing the challenges of managing information and one's environment.
The Language Pathway	Supporting the capacity for using receptive and expressive language, as well as spoken and written language, across contexts.
The Psychological Pathway	Encouraging student self-confidence, self-esteem, self-acceptance, and the ability to control one's emotions.

Reggio Emilia, the Summerhill School, the Riley School, the use of storytelling, play, and hands-on experience, and the Comer Process all represent innovative ways to address human biological needs using nonlinear methods of education. No one method is appropriate for all educational contexts. Many more innovators are currently transforming their local educational environments in response to their own ideas and those gleaned from the work of others. If you have not already begun to transform your practices in teaching and learning, we invite you to begin.

Section 7: Our Children Are the Future

"If the doors of perception were cleansed everything would appear to man as it is, infinite." - William Blake

The concept of ecology serves as an organic paradigm for explaining complex educational processes and predicting possible outcomes. This paper has examined the ecology of contemporary learning environments that bring learning into harmony with our biological origins. We argue for a renewal of human perception about effective ways to learn, to teach, to manage schools, and to plan curricula, and recommend the adoption of old and new educational practices based on a deeper understanding of the biological needs that underlie our species.

Our purpose has been to approach sustainability in a way that teaches future generations how to think in a sustainable way, become more and more sustainable over time, and pass sustainability onto their children so that humans may realize a sustainable future. We hope that our readers view our thought processes as a valid and effective approach to sustainability and are convinced of the need for teachers at all levels to address student biological needs as a way of encouraging learning. We urge all teachers to own their responsibility for educating the next generation to become sustainable by inviting students to embrace the necessary changes to preserve and heal our ecological system. We also want fellow researchers to recognize our approach as a reasonable way of doing educational research.

Our role as educators in promoting sustainability has just begun. We humans need all applicable ideas and willing participants to learn to live in harmony with the earth. We invite you to join us in transforming education for our collective well being.

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Notes

¹ The assertions in this and other sections of this article about the hunter-gatherer lifestyle and the human biological needs arising from it have been synthesized from a number of sources: Capra 1982; Bernhard and Glantz, 1992; Diamond, 1987, 1999, and 2005; and Olson, 2002.

² Quote from Eric Hoffer retrieved from <http://www.erichoffer.net/quotes.html> on 5-2-10.

³ Charles Eisenstein quote from Eisenstein, C. (2007). *The Ascent of Humanity*. Harrisburg, PA: Panentheia Press. p. 316.

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- ⁴ Randall Bass quote from Bass, R. and Good, J. W. (2004). Educare and educere: Is a balance possible in the educational system? Educational Forum, Winter 2004.
- ⁵ Brunner, J. (1986). *Actual Minds, Possible Worlds*. Cambridge: Harvard University Press. P. 106
- ⁶ E. O. Wilson quote retrieved from http://www.brainyquote.com/quotes/authors/e/e_o_wilson_2.html on 5-22-10.
- ⁷ Minnesota Preparing Future Faculty: <http://www1.umn.edu/ohr/teachlearn/graduate/pff/>.
- ⁸ Edgar Morin quote from Morin, E. (1999). *Seven Complex Lessons in Education for the Future*. UNESCO Publishing: Paris.
- ⁹ Wikipedia, <http://en.wikipedia.org/wiki/Sustainability>, retrieved 5-19-10.
- ¹⁰ Preparing Future Faculty: <http://www.preparing-faculty.org/>.
- ¹¹ John C. Daniels School of International Communication Mission Statement, retrieved from <http://www.johncdaniels.org/> on 5-21-10.
- ¹² The Sound School Regional Vocational Aquaculture Center Mission Statement, retrieved from <http://www.soundschool.com/> on 5-21-10.
- ¹³ As told by S. N. Goenka.
- ¹⁴ Francis Keppel quote retrieved from <http://www.lhup.edu/~dsimanek/eduquote.htm> on 5-22-10.
- ¹⁵ Popular Education News, <http://www.popednews.org>.
- ¹⁶ E.O. Wilson quote retrieved from http://www.brainyquote.com/quotes/authors/e/e_o_wilson_2.html on 5-22-10.
- ¹⁷ Mission Impossible was a CBS television show in the 1960s about a team of secret U.S. government agents. Each team member was selected for his or her specific expertise. Together team members achieved what would not have been possible for any one team member to do. This is an excellent example of not only team work, but of qualities that emerge from an interaction that do not exist in any one of the interacting elements. The TV show was subsequently reproduced as a set of three motion pictures.
- ¹⁸ Antonio Machado quote from Machado, A. (1912). *Proverbs and songs*. Plains of Castille.
- ¹⁹ Bill Clinton quote from his remarks at a ceremony announcing the Annenberg Foundation's grant of a half billion dollars to the Essential Schools Coalition.
- ²⁰ Information on Reggio Emilia Schools retrieved from <http://www.youngchildrenslearning.ecsd.net/reggio%20emilia%20philosophy.htm> and <http://www.youngchildrenslearning.ecsd.net/reggio%20emilia%20philosophy.htm> on 5-30-10.
- ²¹ Information on Summerhill retrieved from <http://www.summerhillschool.co.uk/pages/index.html> on 5-30-10.
- ²² Summerhill. A Tiger Aspect Production for CBBC/BBC Four.
- ²³ Gregory Bateson quote retrieved from *Mind and Nature, III Metalogue: Why Do You Tell Stories?* <http://www.oikos.org/angelsmetalogue.htm> on 5-31-10.
- ²⁴ Riley School information retrieved from <http://www.autognomics.org/Education-and-Learning.html> on 5-30-10.
- ²⁵ Skye Hirst comment on the Riley School retrieved from <http://www.autognomics.org/Education-and-Learning.html> on 5-30-10.
- ²⁶ Quote from a 1910 interview with Henri Poincaré. Translated from the French: "L'expérience est la source unique de la vérité : elle seule peut nous apprendre quelque chose de nouveau ; elle seule peut nous donner la certitude. Voilà deux points que nul ne peut contester." Retrieved from <http://www.forum-metaphysique.com/biologie-physique-mathematiques-paranormal-f53/la-physique-quantique-pour-les-nuls-t4164.htm> on 6-1-10.
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- ²⁸ Albert Einstein quote retrieved from http://www.quotationspage.com/quotes/Albert_Einstein/ on 5-31-10.
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³⁰ Information on the Baltimore program on urban gardening retrieved from [\[http://www.livingclassrooms.org/hands-on/gardening.html\]](http://www.livingclassrooms.org/hands-on/gardening.html) on 5-31-10.

³¹ Information on the Chesapeake Bay program retrieved from [http://www.livingclassrooms.org/hands-on/shipboard.html\]](http://www.livingclassrooms.org/hands-on/shipboard.html) on 5-31-10.

³² Information on the Bay Buddies program retrieved from [\[http://www.livingclassrooms.org/hands-on/bay-buddies.html\]](http://www.livingclassrooms.org/hands-on/bay-buddies.html) on 5-31-10.

³³ Comer Process information retrieved from <http://medicine.yale.edu/childstudy/comer/> on 5-30-10.

³⁴ Comer Process information retrieved and adapted from <http://frank.mtsu.edu/~itconf/proceed02/15.html> on 5-30-10.