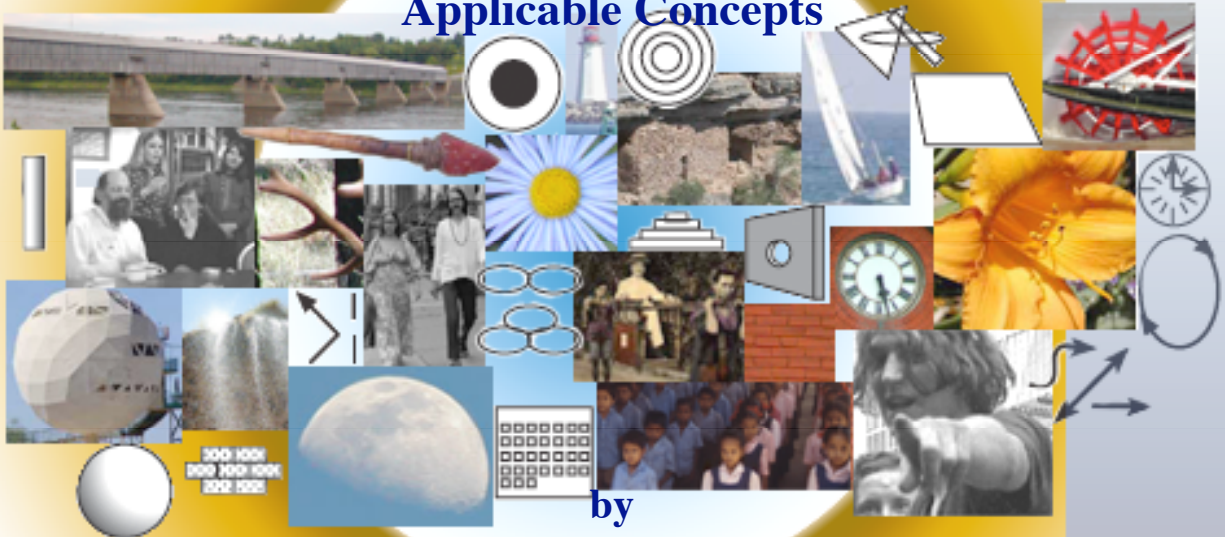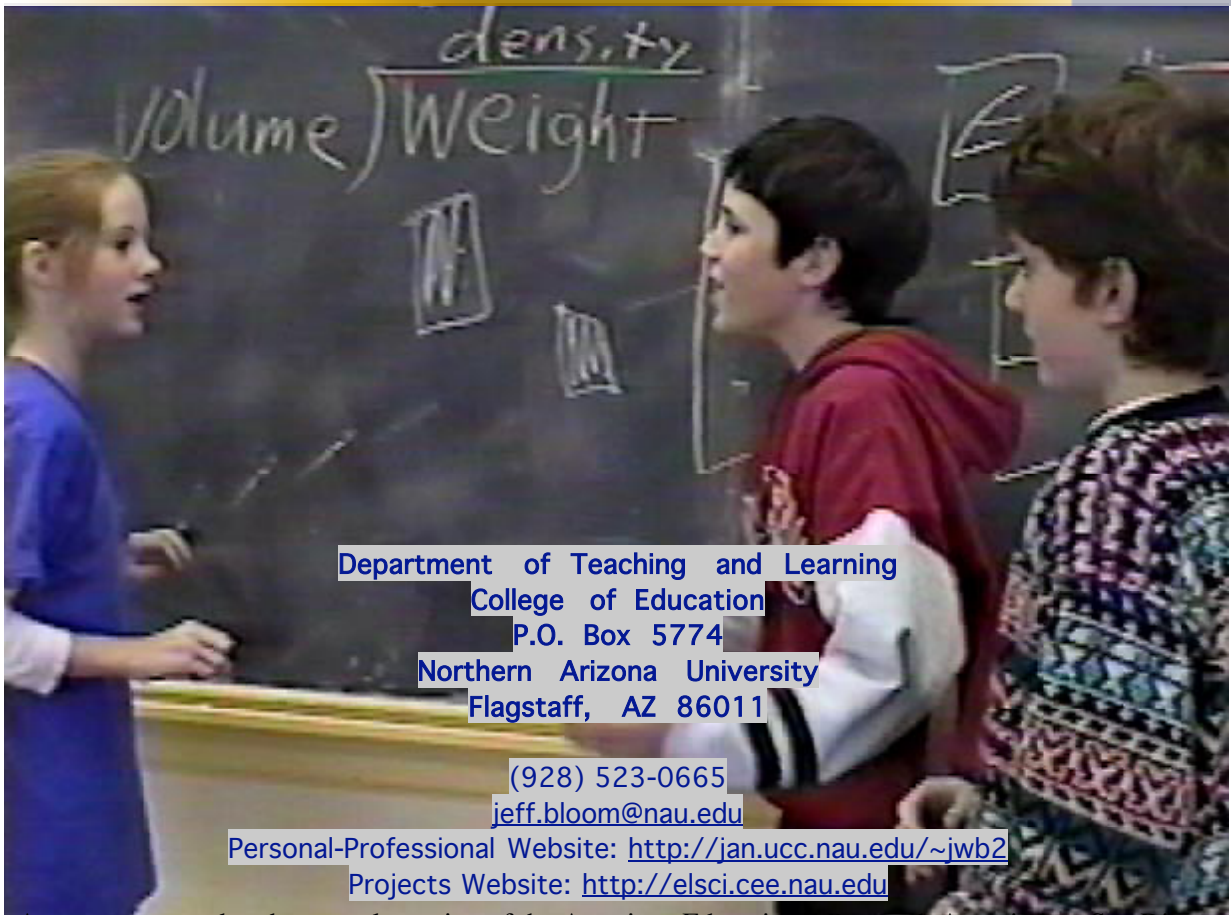# Extending the Analysis of Chaotic and Complex Systems in Education: The Use of Metapatterns and Other Broadly Applicable Concepts

by

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Table of Contents

Introduction

This booklet provides a conceptual and theoretical background in metapatterns (Bateson, 1979; Bloom, 1999, 2000, 2001a, 2001b, 2001c, 2002; Volk, 1995) and how they can be used (a) as frameworks for the analysis of qualitative data; (b) as design frameworks for establishing school, classroom, and professional communities; and (c) as conceptual foci and organizers for science and integrated curricula. The primary emphasis is on the use of metapatterns (with connections to chaos and complexity theories) in the analysis of research data. a

Metapatterns, a term coined by Gregory Bateson (1979), are broadly interconnecting concepts or patterns of patterns that span multiple disciplines and aspects of human experience. Specifically, they are organizing patterns that possess general (universal) functional properties in evolving systems, including natural (biological and physical), technological, social, and cognitive systems (Volk, July, 2002, personal communication). The core meaning or meanings associated with each metapattern are common across occurrences in all disciplines or facets of experience. In other words, they also act as powerful analogical and metaphoric tools that extend the development of complex understandings.

From the perspective of data analysis, metapatterns not only provide a framework for identifying patterns, but also provide a way for situating the data in more complex contexts. For example, in a recent study (Bloom, 2002), elementary teachers' concerns about teaching science through inquiry centered on the conflicting messages from their superintendent. In this case, the hierarchy of the school district created a disparate or separating binary, in which teachers felt that the emphasis on increasing test scores overrode the superintendent's expressed desires to teach more science. From identifying the patterns of hierarchies creating binaries in the specific instance of the school district, the context can be extended to identifying similar patterns in schooling, in general, and in other hierarchical contexts.

In addition, as conceptual foci, metapatterns can be used to enhance children's learning of science concepts in ways that are more complex, as well as in ways that allow for connections to everyday experiences and to concepts in other disciplines. Since metapatterns are evident as primary organizing patterns in evolving systems, they address many of the national and state standards and, at the same time, extend the conceptual foundations in more complex ways.

Additional Background Information

As mentioned in the abstract, the notion of metapatterns was originally conceived of by Gregory Bateson (1979) as a way of exploring the fundamental connectedness of the phenomenal world. His singular "pattern which connects" was an attempt to find the ultimate underlying theory or metapattern of everything. Since that time, numerous people have worked with Bateson's ideas, but Tyler Volk's book, *Metapatterns: Across Space, Time, and Mind*, was the first work to identify and explore a variety of common metapatterns and their connections across disciplines and the life experiences of individuals and cultural groups.

Metapatterns are not only evident in physical phenomena, but appear and are used as analogical and metaphoric descriptors in many different contexts. Although specific meanings are associated with the appearance of metapatterns in different contexts, more fundamental meanings are shared among contexts. For example, spheres, in the biological sense, are particularly significant as the simplest form of containment and as forms that minimize surface area to the contained volume. In physical forms, such as planets or other spherical objects, the

significance may not only include a simplicity of containment, but also omni-directional strength and cohesion. As domes in architecture, the notion of strength is again significant, as well as a "feeling" of containment and spaciousness. In renaissance paintings, halos as spheres indicate a sense of spaciousness, wisdom, and equanimity. In all of these different contexts, sphericity is essentially a sense of optimization or minimization -- of surface area to volume, of containment, of strength and durability, of form. From a metaphoric and analogical perspective, the notion of sphere often is used to describe context, such as in "sphere of friends" or "sphere of consciousness." In such uses, there is a sense of containment, durability, and equanimity. It is this metaphoric sense of sphere or sphericity that is especially significant in describing and representing data in terms of context. These contexts may include a classroom, a school, a conceptual area, a child's context of meaning (Bloom, 1992), or a particular grouping or cluster of individuals. Although such use may seem fairly obvious, the meanings involved in such an application allow for a common "language" or system for describing and comparing a variety of contexts (i.e., spheres).

In addition, as other metapatterns are introduced in the data analysis process, the interactions among them begin to develop complex patterns and relations. For example, as two spheres interact, such as a community of teachers in schools and the community of parents, specific relationships arise and can be depicted two-way relationships of tubes and or uni-directional relationships of arrows. Such relationships may develop further as disparate (dysfunctional) binary relationships or as unifying binaries. Closer examinations of such relationships may provide insights into how conflicts in disparate binaries can be resolved.

In the previous example the interactions and relations between the metapatterns is somewhat simplistic. In practice, the analytical process is one of proceeding through layers – uncovering more complex relationships in each layer. At more profound layers, the researcher begins to see patterns of interactions among multiple metapatterns. Uncovering such complex patterns create intricate webs of relationships, from which new insights and understandings of contexts arise.

PART I
Metapatterns and Chaos and Complexity

Metapatterns – An Overview

General Introduction

Metapatterns, a term coined by Gregory Bateson (1979), are broadly interconnecting concepts or patterns of patterns that span multiple disciplines and aspects of human experience. Specifically, they are organizing patterns that possess general (universal) functional properties in evolving systems, including natural (biological and physical), technological, social, and cognitive systems. The core meaning or meanings associated with each metapattern are common across occurrences in all disciplines or facets of experience. In other words, they also act as powerful analogical and metaphoric tools that extend the development of complex understandings.
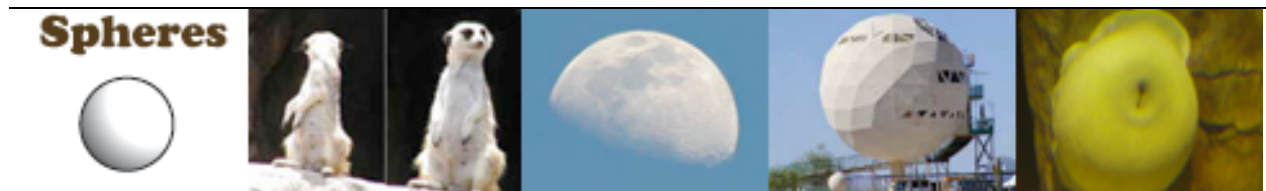
Spheres

Background

Spheres and the tendency towards sphericity are common forms in the sciences, as well as in other disciplines. As physical forms they maximize strength and durability, have a reduced surface area to volume ratio, and minimize environmental contact. In more general terms, the fundamental meanings underlying this form involve equanimity, omni-directionality, simplification, and containment. Spheres and sphericity can be actual physical forms as well as invisible and metaphoric senses of form. In contending with the sense of sphericity, the forms can range from near perfect spheres to partial spheres to squared-off and box-like forms. When nested together, spheres can form holarchic layers.

Examples

In science: cells, many fruits (e.g., apples, spheres, cherries, tomatoes), planets, stars, eyes, heart, skulls, eggs and spores, bubbles, droplets, biosphere, ecosystem, inflated puffer, jellyfish, sea urchin, etc.
In architecture and design: domes, geodesic domes and spheres, atria, light bulbs and fixtures, etc.
In art: halos in Renaissance paintings, spherical forms in paintings and sculpture, pottery bowls, etc.
In social sciences: spheres as communities, spheres as context, spheres as schemata (as in schema theory), etc.
In other senses: sphere of influence, sphere of friends, sphere of consciousness, sphere as neighborhood, etc.

In Research

As a research framework, we have found the sense of sphere useful in describing and representing (a) schemata as cognitive context; (b) individual, social, physical, and political contexts (e.g., cliques, classrooms, schools, the institution of schooling, etc.); and (c) conceptual or theoretical frameworks.

Background

As physical forms, tubes seem to have three fundamental aspects, which, in some cases, appear as one aspect and, in other cases, are combined in one form. One aspect involves the notion of strength and support along a linear dimension. The second aspect is that of bidirectional or unidirectional transport of energy, materials, or information. The third aspect involves the ability to penetrate, extend, or grow along a linear dimension. In biological forms, they increase the surface area to volume ratio, compared to spheres. In a more general sense, tubes involve the concepts of linear strength, linearity, extension or bridging, transfer or flow of information, and connection or relationship.

Examples

In science: nerve cells and fibers, blood vessels, appendage and some other bones, phloem--xylem, stems--branches, hair, cilia, flagella, digestive tract, streams and rivers, lava tubes, pine needles, eels, snakes, worms, spider webs (tubes making sheet), bodies of airplanes, rockets, etc.

In architecture and design: hallways, internal support structures, elevator shafts and stair wells, highways, trails, tunnels, bridges, electrical wires, pipes, networking cables, utility poles, suspension bridge (traffic flow, support structures, support cables), etc.

In art: shape, brushes, pottery forms, sculpting forms, etc.

In social sciences: relationships between people, connecting lines in concept maps, patterns of interaction, lines of communication, patterns of movement, support mechanisms, etc.

In other senses: tobacco pipes, cigars, syringes and needles, etc.

In Research

In research, tubes as relational connections are useful in representing the complexity of connections between ideas, individuals, and specific contexts. Such connections are common in concept and other types of semantic mapping, thematic diagrams of discourse, diagrams representing a wide assortment of relationships, etc. They also can be used in depicting movement within a physical setting or within psychological contexts as growth of knowledge or ability along a specific dimension.

Sheets

Background

As physical forms, sheets maximize transfer across surface areas, maximize surface area to volume ratio, and extend or grow two-dimensionally. In general terms, sheets represent capture, contact, and movement across a plane. In addition, when put together, they can form layers and can act as borders. Spheres and tubes can be made of sheets.

Examples

In science: leaves, surface tension, membranes, individual layers of the Earth and atmosphere, fins, airplane wings, skates and rays, films, snow coverage, etc.
In architecture and design: walls, open areas as in large convention centers, fans and windmills, sails, turbines, etc.
In art: canvas, shapes, etc.
In social sciences: movement within a space, separation, etc.
In other senses: clothing, rain coming down in sheets, bed coverings, parking lots, etc.

In Research

Each layer in an organization can be represented and discussed as sheets. Movement in an open space can be described as sheets. However, more often sheets are discussed within the contexts of borders and pores and layers.

Layers

Background

Layers point to increasing complexity as sheets, spheres, tubes, and other fundamental patterns combine in linear or nested layers. The process of layering is a building up of order, structure, and stabilization.

Hierachies

Background

Hierarchies tend to be depicted as pyramidal arrangements of sheets. Hierarchies are identified as the relationships between layers become evident. In most cases, hierarchies are exemplified by power or control moving downward. In other cases, the top layers may indicate greater importance or significance. Information, materials, or energy move upward. They tend to create stratified stability. However, this stability may depend upon the types of binary relationships and other patterns that are created within the overall structure.

Examples

<u>In science</u>: trophic layers, phylogenetic trees, animal societies (bees, ants, chimpanzees, wolves, etc.), etc.
<u>In architecture and design</u>: pyramids, building design and layout, etc.
<u>In art</u>: as form, etc.
<u>In social sciences</u>: governmental and organizational structures; classrooms, schools, and schooling; some learning theories; etc.
<u>In other senses</u>: information trees, branching decision trees, etc.

In Research

Hierarchies can be used to identify social and institutional structures, conceptual organization (curricular and cognitive), and individuals' perceptions of their institutions and the relationships within these institutions. Hierarchies themselves can lead to the establishment of certain kinds of relationships (binaries, etc.) and other metapatterns within the social context.

Holarchies

Background

A holarchy is a nested system of layers in which the units (wholes) within one layer are parts for the wholes in the next larger, encompassing layer. Holarchic layers can be used to describe certain types of social, institutional, and political organizations, as well as structures in science and other disciplines. In holarchies the wholes at each level have particular kinds of relationships with the other wholes on that same level, and these relationships change as we move up the nested layers from physics to organisms to social systems. The relationships between layers in holarchies tend to be ambiguous and more difficult to describe.

Examples

In science: rose flowers, the Earth and atmosphere, atoms, bodies of organisms, holarchic layers of complexity in organisms (from DNA/RNA components to the whole), solar system, galaxies, etc.
In architecture and design: some building and community designs, etc.
In art: forms as depicted, etc.
In social sciences: communities (as described by Jean Lave and Etienne Wenger), many tribal societies, democracy in its purest form, etc.
In other senses: mandalas, apprenticeships, etc.

In Research

Holarchies can be effective in describing communities of practice. Wenger's notion of community is holarchic with embedded layers of meaning, identity, participation, and even the sense of community. Schema theory describes layers of meaning and connection within a conceptual area. The physical layout of classrooms and schools can create a semiotic (sign or symbol) sense of holarchy (or hierarchy).

Clonons

Background

The notion of clonons is one to build simple holarchies, in that specific objects or ideas are repeated to create layers of embeddedness. The notion of clonons falls within the scope of holarchies, in that specific objects or ideas are repeated to create layers of embeddedness. As with the process of cloning, a specific object can be replicated. Clonons can build wholes and each whole can be a clonon of larger set.

Examples

In science: identical cells in different layers of tissue, protons, neutrons, electrons, worker ants, each fish in a school, identical atoms in a molecule (e.g., two clonons of hydrogen joining a holon of oxygen to form a holon of a water molecule, which in turn become a clonon of water molecules in a cup of water), etc.

In architecture and design: bricks in a wall, tiles on a floor or ceiling, each light fixture in ceiling, each office or room on a floor, each floor in a building, windows in skyscraper, each house in a subdivision, etc.

In art: each brush stroke in a painting, each decorative design unit in a pottery bowl, each point in a pointillism painting, etc.

In social sciences: each individual in a community or society, each client in a business, each factory work at a specific point in an assembly line, etc.

In other senses: each tomato on a tomato plant, each tomato plant in a tomato garden,

In Research

Clonons (and their relationship to holons) may be useful in identifying parts of wholes and their similarities in function, view, treatment, etc. Are students just another "brick in the wall" (as contended by Pink Floyd)?

Holons

Background

Holon, as mentioned previously, refers to a whole, which is often comprised of clonon parts or sets of clonon parts. Holons themselves can become clonons of even greater wholes. The idea of holons (in contrast to indistinguishable clonons) is that holons are functionally and structurally distinct parts on the level of a holarchy. Holons are like organs, on different scales of wholes. Thus the body's holons are heart, lungs, brain and so forth, which themselves are composed of many clonons, the relatively indistinguishable heart cells, liver cells, and so forth.

Examples

In science: a planet, a solar system (made of holons-planets that become clonons of the solar system), an atom is a holon of three fundamental types of clonon particles, atoms become clonons of larger holon molecules, etc.
In architecture and design: buildings, a community, etc.
In art: subjects, figures formed from points or strokes, a sculpture, etc.
In social sciences: a concept, a community or society, an action holon of component clonon actions, a family, a class of students, etc.
In other senses: a wall or fence, an archway made of stone clonons, a gang or clique, etc.

In Research

As with clonons, holons can help to describe wholes and related clonon parts. Are certain entities treated as holons or clonons? Do holons become clonons of even greater holons?

Borders and Pores

Background

Borders involve the concepts of protection, separation of inside from outside, containment, and barrier or obstacle. With pores, borders regulate the flow and exchange of materials, energy, or information. Small pores heighten regulation and reduce flow, while larger pores decrease regulation and increase flow. Borders can be visible entities, fuzzy, or invisible. Physical borders tend to be built of sheets of repeating parts (clonons).

Examples

In science: cell membranes and osmosis, skin and pores, eyes, ears, nose, mouth, stomata, the Earth's crust and volcanoes, clouds with fuzzy borders, atmosphere, ecotones, edge of a pond, etc.

In architecture and design: walls with doors and windows, roof and skylight, etc.

In art: depicted forms, frame with canvas as opening pore to another world, pottery bowl or vase with circular pore, etc.

In social sciences: personal space, psychological and social obstacles, problem as border with paths to solutions as pores, physical space divisions and openings, social barriers, borders between social strata, racism and other biases as barriers, propaganda as a barrier to truth, borders between countries with border crossings and immigration pores, etc.

In other senses: borders and openings in feng shui, borders between properties, airline security, etc.

In Research

Borders and pores can describe a wide variety of psychological, social, and physical phenomena. Hierarchies, binaries, and so forth, can establish systems with borders. Prior understandings can be barriers or pores to developing more accurate understandings. Borders can be created by semiotics, in terms, of room arrangements, verbal cues, etc.

Centers

Background

Centers act to stabilize the whole, provide resistance to change, and provide for organization of the whole. They can act as attractors for autopoietic (self-generating, self-sustaining) systems. In a more general sense, they can imply importance or significance and a sense of centricity. As such, centers can radiate relations to other centers, information, and so forth.

Examples

In science: nucleus, strange attractor, queen ant or bee, fulcrum, dominant male in primate societies, center of gravity, heart within circulatory system, brain within nervous system, etc.

In architecture and design: main office, central meeting places, central structural supports (such as elevator shafts in skyscrapers), etc.

In art: the central figure or object as subject; the organizing principle or emotional focus of a piece of art, etc.

In social sciences: president, governor, major, dictator, leader, teacher, principal, central physical site of specific types of activity, organizing principles of societies and other groups, heart as center of individual in many indigenous cultures, brain as center of individual in most technologically developed cultures, focus of life or activity (e.g., individuals may consider self, family, work, sport, hobby, or spiritual efforts as center), ego or self centric, anthropocentrism, conceptual prototype, conceptual defining characteristics, etc.

In other senses: altar in a church, shrine in a temple, a deity or deities, sacred sites (Mecca, Bodhgaya, Jerusalem), shopping center, etc.

In Research

In research, the identification of centers can help in defining the importance, significance, operational or organizational basis within particular contexts, etc. A center may be a particular claim or event involved in generating and maintaining extended arguments or discussions. The teacher, principal, or group leader can act as a center. Frequently, centers may be comprised of certain types of binaries, trinaries, or other levels of complex relations.

Background

Binaries are the simplest form of complex relations. More complex relations involve increasing numbers of components (e.g., trinaries, quaternaries, and so forth). Such binary relations are the most economical (in a variety of senses) way to generate complex wholes with significant new properties. Binaries involve senses of separation and/or unity, duality, and tension. They also provide for a synergy between parts and wholes.

Examples

In science: bilateral symmetry (including two eyes, nostrils, ears, appendages, etc.); positive and negative particles, ions, electrodes, etc.; male and female; opposing forces; diurnal and nocturnal; dorsal and ventral; space and time; acid and base; DNA with component pairs and paired helices; inhale and exhale; respiration and photosynthesis; mass and volume; high pressure and low pressure; perception as the recognition of difference; form and function; acceleration and deceleration; etc.

In architecture and design: inside and outside and the associated dynamics between them in buildings; entrance and exit; up and down passages;

In art: light and dark; monotone and multicolored; tensions between parts; attraction and repulsion (emotionally); etc.

In social sciences: report talk and rapport talk; leader and follower; positive and negative attitudes; consumer and producer; passive and aggressive; trust and distrust; unity and disunity or separation; etc.

In other senses: distal and proximal; all or nothing; night and day; open and closed; on and off; asleep and awake; old and young; love and hate; etc.

In Research

Binaries are useful in identifying a variety of relationships, tensions, etc., as well as a variety of binary-based assumptions and expectations imbedded in different contexts. Binaries are frequently created by hierarchic and holarchic social and political situations and serve as the basis of centers, breaks (change, transformation, etc.), and arrows. They also interact or are involved with spheres, sheets, tubes, borders and pores, time and calendars, and cycles.

Types of Binary Relationships

Gregory Bateson:	Complementary	Symmetrical	Reciprocal
Metapattern specific:	Disparate Binary	Competitive Binary Commiserate Binary	Collaborative Binary
Metapattern general:	Divergent Binary Separating Binary	Divergent Binary Separating Binary	Convergent Binary Unifying Binary
Other Descriptors:	Dominant-Submissive Controlling-Subservient Directive-Passive	Dominant-Dominant Submissive-Submissive Vying for control Oppositional	Cooperative Mutuality Supportive

Background

Arrows indicate flow, progression, directional links and relationships, and directionality in general. Arrows are often linked to time (as an arrow) and sequences. Arrows of time are equivalent to tubular relations in space. Arrows also depict specific directional relations between binaries.

Examples

In science: chemical reactions, acceleration, nerve transmission, vectors, velocity, osmosis, rivers, currents, wind, volcanic flow, bird flight, etc.

In architecture and design: traffic flow, sequences in construction, escalators, directionality in lighting and décor; structural strength in supporting weight; etc.

In art: as objects, as eye movement in looking at piece of art, choreography, drama, etc.

In social sciences: directional relations, movement, flow, stages and sequences, etc.

In other senses: journeys and pilgrimages; travel plans; agenda; etc.

In Research

Arrows are particularly useful in identifying and describing directional relationships between people, in conversations, in cognition, etc.), movement and flow in social contexts; sequences and stages in individual and social development.

Time and Calendars
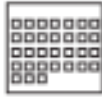
Background

Time can be considered a binary of movement and memory and can be observed by connecting several spaces. Time can be seen as an arrow or cycle. Time also is evident as counting, progression, and sequences.

Examples

In science: biological clocks, animal behavior, velocity, acceleration, time-space phenomena, etc.

In architecture and design: how time is defined and related to in particular contexts; at Arcosanti (an environmentally situated desert city in Arizona) all buildings are multiuse in order to minimize building use down-time;

In art: in drama, music, dance, and other performance arts time is the fundamental organizing pattern, as well as fundamental to the perceptual experience; etc.

In social sciences: calendars, clocks, history, sequences and stages in development, etc.

In other senses: time to kill; wasting time; time management; timeliness;

In Research

A variety of events and objects mark time in schooling and other contexts. Within these contexts time is utilized and related to in different ways, but often maintain characteristics of the particular institution or culture. In some situations, people from different cultures relate to time in very different ways, which can result in social dissonance and a variety of other conflicts.

Breaks

Background

Transformations; change; leaps; shifts; sequences of stages; dilemmas and decisions.

Examples

<u>In science</u>: chemical reactions, metamorphosis, evolutionary change (punctuated equilibrium), energy transformations, phenotypic plasticity, point of change from action to reaction, waterfalls, branching, etc.
<u>In architecture and design</u>: divisions of space and activity, vehicle brakes, etc.
<u>In art</u>: perceptual shifts, design changes, etc.
<u>In social sciences</u>: insights, stages in development, events that change psycho-social states, etc.
<u>In other senses</u>: divorce, death, birth, marriage, crashing waves, breakthroughs, etc.

In Research

Breaks are useful in describing changes in cognition, between events in a classroom, in thematic branching during classroom discourse, and so forth. By demarcating such breaks, we can proceed to examine such events in more detail by looking for the events or situations that have contributed to the changes.

Cycles

Background

Cycles are repetitions in space or time, such as, circulations, waves, repetitive routines, etc. Interactions of cycles and arrows create spirals or helices.

Examples

In science: Kreb's cycle, Earth's rotation and revolution, lunar phases, animal movement, biological rhythms, breathing, water cycle, carbon cycle, nitrogen cycle, seasons, tides, bird songs, light, sound, cybernetic feedback loops, etc.

In architecture and design: heating and cooling systems, movement patterns in buildings, etc.

In art: perceptual "movement," musical compositions, choreography, etc.

In social sciences: repetitive actions, routines, rituals, helical patterns of themes running through discourse and other psycho-social situations, etc.
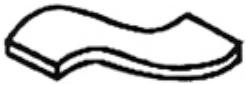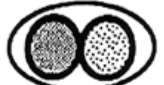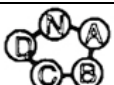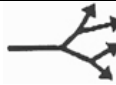
In other senses: laps in a race, wheel of karma, etc.

In Research

Identifying cycles within social situations, cognition, teaching, classrooms, and schools can provide a foundation for understanding the basic patterns of the situations under examination. Further examinations can lead to understanding what keeps such cycles going, what interrupts (breaks) such cycles, and how such cycles interact with other cycles or situations.

Icons Associated with the Discussions of Each Metapattern in Volk (1995)

Spheres	Majesty of the Sphere	The Grape-Moon Koan	Small Surface, Great Volume	Buckyballs, Domes, and Shells	Spherituality
Sheets and Tubes	Shape's Spectrum	Functions of Flatness	Tubes for Transport	Synergies of Things and Relations	
Borders	Bulwarks of Being	Ins and Outs	Separation and Connection	Doors and More as Metaphors	Border Mind
Binaries	Triumph of Twos	Families of Simplest Complexities	Across Parallel - Pairs	Beyond the Binary	
Centers	Geometry of Suns and Kings	Two Great Nucleations	Brains, Bees, and Alphas	Government, God, and Gaia	
Layers	Vision of the Rose	Hierarchies and Holarchies	Holons and Clonons	Handfuls of Holons	Alphabetic Holarchies
Calendars	Space, Time, Movement, Memory, and Mind	Holons and Clonons in Cycles	Taking Breaks	Resetting the Great Count's Arrows	
Arrows	Galileo's Free Fall	Arrows in Property Space	Linked Ups and Downs	Arrows In and Out	Arrows in Possibility Space
Breaks	Time's Waterfalls	Time's Skin	Sequences of Stages	Breakthroughs	
Cycles	Rounds in Time	Cycles Propelling Arrows	Music of the Cycles		

Overview of Chaos and Complexity in the Social Sciences

| PATTERN | ➾ | PROCESS | ➾ | STRUCTURE |

These three elements comprise the fundamental aspect of chaotic and complex systems.
Associated metapatterns are listed on the right side.

Pattern of organization (autopoiesis as self-generating/-maintaining/-amplifying)

Circular patterns of discourse	
• Cybernetic Feedback Loops	Cycles
Spiral patterns of discourse	
• Feedback Loops that "feed" information to interchanges at later times	Arrows affect cycles to create spirals and helices along thematic tubes.
Symmetrical patterns of relationship	Competitive binaries
• Conflict situations	Divergent binaries
• Generate divergence ➔ emergent, complex	Binaries and arrows
Complementary patterns of relationship	Disparate, dominant-submissive binaries
• Conflict situations	Divergent binaries
• Generate divergence	Binaries and arrows
Reciprocal patterns of relationship	
• Balanced, negotiative relationships	Collaborative, unifying binaries
• Striving for consensus	Convergent binaries
Student ownership	
• Over content (i.e., ideas) and process	Centers with radiating tubes of relations

Process of production

✦ Continually generates structures that manifest as patterns of organization	
Passion	
• passion is a necessary "energy" or "fuel" for sustained engagement	Center
Cognition	
• inferring, generating supportive or counter examples, explaining, etc.	Centers, spheres, borders-pores, tubes, cycles, arrows, layers, etc.
• manifest as feedback loop patterns (circular and spiral)	Cycles, arrows

Structure

Micro-Level	
Emergent conceptual content	
• Not predictable (because of variation in ideas and process)	Centers, arrows, breaks, etc.
• Development of increasingly complex understandings	Interactions of centers, tubes, cycles, arrows, spheres, etc.
Macro-Level	
Dissipative Structures	
• Self-maintaining, self-organizing, self-amplifying	Interactions of cycles, centers, arrows, etc.
• Far from equilibrium	

- • e.g., Degree of dissonance among students   Binaries
- • Non-Linear   Cycles, arrows
- • Processes that generate patterns
  - • Continually reinforce and perpetuate overall structure
  - ✦ Students' cognition (Process) as expressed in dialogue manifests as circular, spiral, and helical feedback loops (Patterns) that carry ideas and concepts forward.
- • Aspects
  - • Attractor (initial)   Center
    - • Impetus for argument
    - • Can be discrepant event or contentious knowledge claim
  - • Bifurcation Points   Breaks in arrows, cycles, tubes, etc.
    - • Attractors that arise during discourse
    - • Initiate divergent lines of thinking
    - • Are unpredictable

Relations Between Metapatterns and Chaos-Complexity Theories

Chaos & Complexity / Metapatterns	Patterns of Organization	Autopoiesis	Emergence	Feedback Loop	Process of Production	Structure	Dissipative Structures	Attractor	Bifurcation Point
Spheres						X			
Tubes						X			
Sheets						X			
Layers						X			
Borders-Pores						X			
Centers	X	X	X			X	X	X	
Binaries +	X				X	X	X		
Arrows	X	X	X	X	X				
Time-Calendars	X	X	X		X				
Breaks	X	X			X				X
Cycles	X	X		X	X		X		

Complexity and the Interactions between Metapatterns

Although using metapatterns is useful in identifying significant patterns during the analysis of particular sets of data, examination of the interactions among such patterns may yield much more complex understandings. For instance, hierarchically layered social structures may be founded on sets of assumptions that may be based upon divergent binaries (e.g., controller—controlled, power—powerless, efficiency—creativity, etc.). At the same time, such hierarchies may produce divergent binaries, such as, "us—them" attitudes that prevent cooperation between layers and lead to distrust and so forth. Maintaining hierarchies also may involve specific cycles of actions, the establishment of specific types of relations (tubes and arrows), the identification and use of different sites, events, and people as controlling centers. These interactions among many other possibilities can lead to a rich and complex understanding of such situations. Examples of how such interactions have been identified in research appear in some of the figures later in this booklet.

Some additional possibilities of metapatterns, which we have been considering, are listed below. Although these patterns can be explained through the interactions among two or more of the original metapatterns, they seem to be common and distinctive in a variety of contexts.

Emergence: A common term used in chaos and complexity theories, which describes the arising of a new pattern. In these theories, there are two views of patterns in chaos: (a) patterns emerge from chaotic phenomena and (b) patterns are embedded in chaotic phenomena. Examples of emergence include the formation of a tornado, birth, thematic patterns arising from an argument, and so forth. Emergence may involve interactions between centers, cycles, arrows, binaries, etc. The specific interactions depend upon the particular phenomenon.

Clusters and Clustering: Such events appear to be common occurrences, such as in the formation of cliques and other groups of people and animals, towns and cities, the generation of ideas along specific themes, and so forth. Such processes may involve centers, cycles, spheres, tubes, etc.

Reproducing or Replicating: These processes appear in a variety of contexts and describe the generation of similar forms. Examples include sexual and asexual reproduction, building structures (replicating parts and replicating wholes), the generation of a model that replicates a specific event, crystal formation, etc. Such processes may involve interactions between centers, layers (producing clonons and holons), cycles, arrows, etc.

Typologies of Metapatterns

	Bateson's Typology				Volk's Typology			
	Spatial	Temporal	Formal	Relational	Natural Systems (Biological & Physical)	Technological Systems	Social Systems	Cognitive Systems
Spheres	X				X	X	X	X
Tubes	X			X	X	X	X	X
Sheets	X				X	X	X	X
Layers	X		X	X	X	X	X	X
• Hierarchies	X		X	X	X	X	X	X
• Holarchies	X		X	X	X	X	X	X
• Clonons	X		X	X	X	X	X	X
• Holons	X		X	X	X	X	X	X
Borders and Pores	X		X	X	X	X	X	X
Centers	X		X	X	X	X	X	X
Binaries	X	X	X	X	X	X	X	X
Arrows	X	X	X	X	X	X	X	X
Breaks	X	X	X	X	X	X	X	X
Time and Calendars		X	X		X	X	X	X
Cycles	X	X	X	X	X	X	X	X

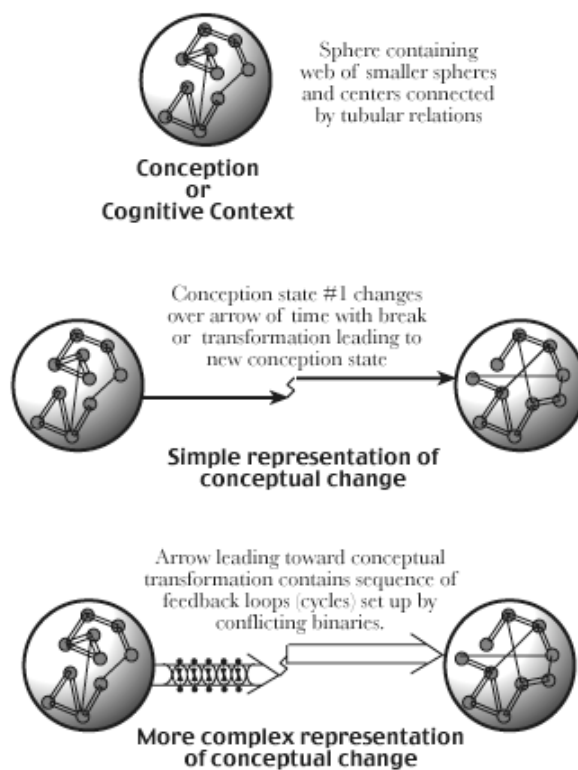| Volk (1995)	Alexander (2000)	Lakoff & Johnson (1980)	Stevens (1974)	Kappraff (1991)	Rico (2000) Writing the Natural Way
Spheres		Concept Unity			Concept Unity
Tubes		Conduit; Relations of Concepts	Bubbles	Networks and Lattices	Relations of Concepts
Sheets			Films		
Layers – Hierarchies; Holarchies; Clonons; Holons	Levels of Scale	Structures of Parts and Wholes	Packing	Packing; Tilings; Proportion	Multiple Clusters
Borders and Pores	Boundaries	Containers; Containment	Partitions		
Centers	Strong Centers	Prototypes; Purpose; Causation			Clustering
Binaries	Contrast	Orientation Maps; Metaphor		Duality; Reflections	Creative Tension; Metaphor
Arrows	Gradients	Paths (Stages, Beginnings & Ends); Sequence; Orientation	Stress (and flow); Growth; Meander		Language Rhythms (Sequences)
Breaks	Roughness	"Into"–Transformation; Creation=Birth	Branching; Explosion; Cracking	Translations	Trial Web
Times & Calendars		Time			
Cycles	Alternating Repetition; Echoes		Vortex; Spiral; Turbulence (flow)	Rotations	Recurrence
	Positive Space				
	Good Shape				
	Local Symmetries			Symmetry	
	Deep Interlock and Ambiguity				
	The Void				
	Simplicity	Substance		Truncation	
				Solidity	
				Similarity	
				Golden Mean	
				Maps	
				Rigidity	
				Space Filling	

Interactions Among Metapatterns

Using metapatterns to describe complex situations provides for the delineation of more specific or subtle processes and events than what may be available within the language used in chaos and complexity theories. In the figure below, we start (at the top) with a fairly simple description of a broad conceptualization represented as a sphere as the containment of sets of related information (e.g., propositions, prototypes, exemplars, etc,). The middle representation provides a simple description of conceptual change as the movement from one conceptual state to another with a break or transformation occurring over time. The representation at the bottom depicts conceptual change in more detail. The arrow moving toward the break or transformation contains a set of feedback loops or cycles that appear as helices (i.e., cycles affected by arrows). Each looping or cycling is initiated by a set of disparate or conflicting binaries that drive the cyclical process.

Sphere containing
web of smaller spheres
and centers connected
by tubular relations

**Conception
or
Cognitive Context**

Conception state #1 changes
over arrow of time with break
or transformation leading to
new conception state

**Simple representation of
conceptual change**

Arrow leading toward conceptual
transformation contains sequence of
feedback loops (cycles) set up by
conflicting binaries.

**More complex representation
of conceptual change**

Figure 1. Interactions among metapatterns as depicted in analyses of cognition

In the previous figure, the representations lead to specific questions about the cognitive states and processes, as well as about the instructional implications:

1. What is the specific "structure" of the conception, including the relations (tubes) between propositions, the propositions or other cognitive aspects (e.g., emotions, values, etc.) that act as central organizing factors (centers), etc?

2. What are the conflicting binaries that set up cognitive feedback loops that lead to potential transformations of the conception?

3. How can teachers introduce sets of binaries or conflicting situations that can stimulate cognition that may lead to transformation?

Although these questions introduce a sense of specificity to our understandings of conceptual change, the context of such change is not quite so certain. In the vast majority of research in conceptual change, the theoretical construct of conceptual change is typically misunderstood (Bloom, 19**). As originally conceived by Strike and Posner (1982), conceptual change was intended to describe a process that involved very broad conceptions (not concepts) on the level of belief and was not intended to provide a template for instruction. However, most research on conceptual change from that time to present has focused on specific concepts and on instructional approaches to such change.

This focus on conceptual change teaching is based on sets of assumptions situated in mechanistic and positivistic worldviews. In other words, researchers tend to view learning and instruction as specific linear processes with predictable outcomes. However, if we view the representations of conceptions and conceptual change in the previous figure, along with the questions posed above, within the context of chaotic and complex systems, the nature of conceptual change adheres more closely to that intended by Ken Strike and George Posner. The process of conceptual change may not be controllable and certainly is not predictable. We may be able to identify and present conflicting binaries, but we cannot predict any timeline for change or what the outcome may be, if any change occurs at all.

In the figure at the right, a representation of complexity of conceptions points to possible reasons as to why change in conceptions is not only difficult, but also unpredictable. What research has tended to ignore is the complex interactions within individuals' cognitive contexts. In addition to the sphere of the particular conception, the personal and idiosyncratic contexts of emotions, values, and interpretive frameworks overlap and influence how specific propositions are "constructed" and how they add to the dynamic of one's understandings.

At the intersection of the contexts of emotions, values, and interpretive frameworks one particular node is included. In such a situation, this node can act as a center (the largest number of tubular relations connect to this node, as well) that maintains the organization and relative stability of the whole. Such deeply embedded central factors make change difficult and unpredictable.

Figure 2. Complexity of conceptions.

What is difficult to represent in such diagrams is the fact that knowledge and understandings are dynamic and not static. The nature of diagrams themselves seems to be embedded in mechanistic and positivistic contexts. Where cognition is fluid, the terms "structure of knowledge" and "constructing knowledge" are misleading (they appear in quotes in the previous discussion for just this reason). The tubular relations between propositions, prototypes, etc. appear, disappear, and change over varying spans of time. The affects of emotions, values, interpretive frameworks, among other personal, idiosyncratic contexts changes from moment to moment and in different settings. So, the diagrammatic representations in figures 1 and 2 are just snap-shots in time.
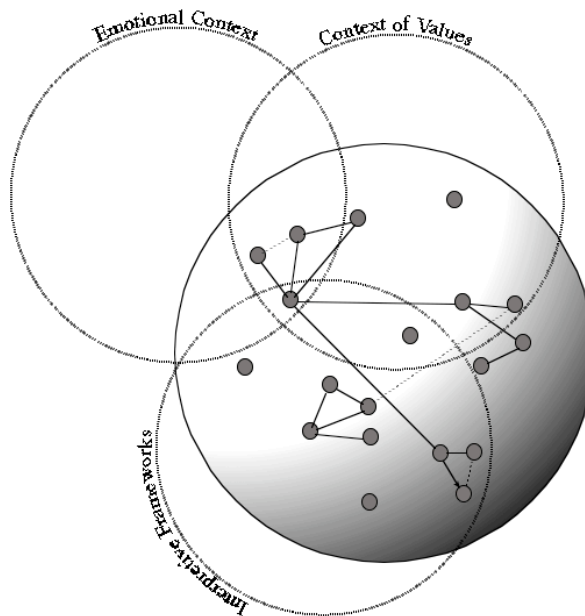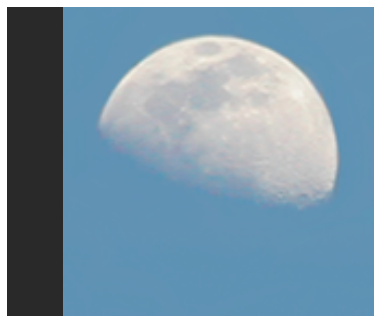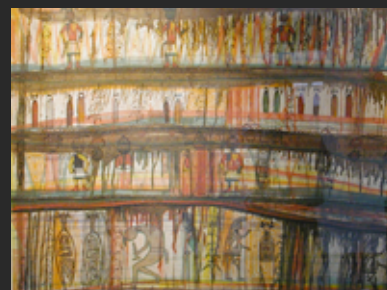
PART II
Examples

Sample Metapattern Photos

Spherical moon with fuzzy day-night border.

Spherical Navajo wedding basket made of spiral (arrows affecting cycle). Design has border with a pore-break to allow for openness and uncertainty.

Painting depicting Hopi holarchic layers of life.

Plankton as spheres and tubes. Holarchic forms with borders and pores, centers, binaries in symmetry, clonons and holons, etc.

Spherical elephant supported on tubes, with multi-purpose tubular nose, ear-sheets for capturing sounds, and binary symmetries.
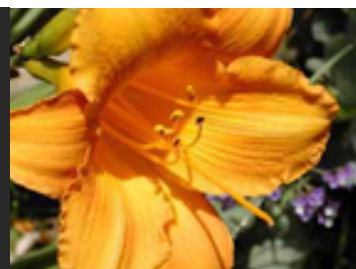
Pine trees near Flagstaff, Arizona… center tubular trunks with branches-breaks radiating from center. Tubular leaves minimize water loss.

Alligator as tube with binaries of ears, eyes, nostrils, and legs.

Flamingo with tubular neck, beak, and legs and tube-sheet feet.

Holarchic flower with sheets forming sphere. Binary sex organs on tubes emerging from center.

Holarchic layers through time in the Grand Canyon. Tubular tree branches with breaks of growth and extensions. Plants emerging from rocks.
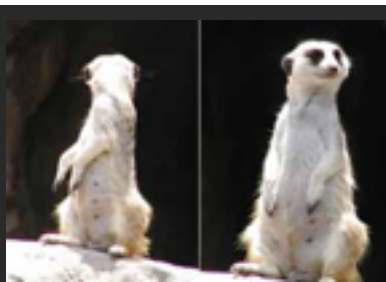

Hippopotamus with binaries of ears, eyes, and nose… spherical eyes and ears as capturing sheets of sphericity.

Sheet-like flowers atop tubular stems with binary sex organs on a single plant.

Spherical kiva ruins near the Grand Canyon. The sphere was one of community containment and equanimity.

Meercat with binaries of nipples, eyes, nostrils, ears, and appendages… examining territorial sphere.

Spherical house along I-40 in western Arizona. Sphere is made of sheets over tubes and supported on a tube, with window-pores.

Spherical Navajo pot with large pore.

Tubular sailboat with sheets to capture wind and propel the boat through an arrow of time.
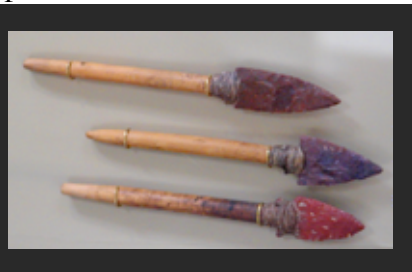

Halifax building supported by tubes with sheets of window pores.

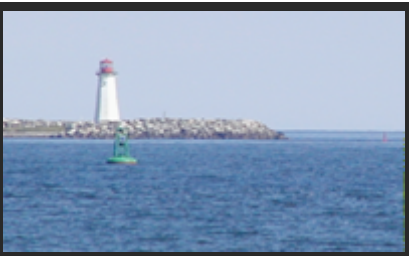Condor with binary sheets made of tubular feathers for flying.

Spherical beetles engaging in the binary that allows new life to emerge as clonons.

Native American arrow-darts.

Cliff dwellings, Montezuma's Well near Rim Rock, Arizona, embedded in holarchic layers of rock. Dwellings of adobe brick clonons forming borders and pores.

Lighthouse as tubular center for sailors, radiating arrows of light in cyclical patterns. Buoy as center guide for invisible tubular channel.

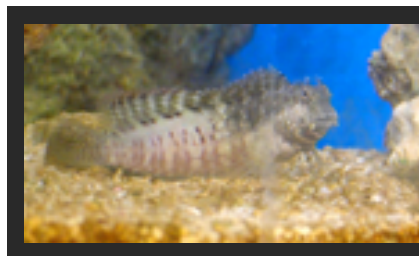Dark layer of fog with fuzzy borders moving into Halifax harbor.

WOW Air's tubular wind sock showing directional arrow of wind.
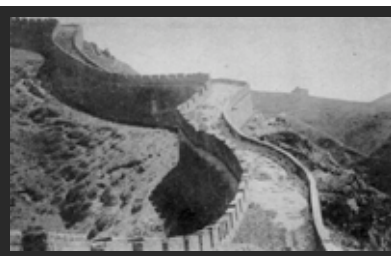

Utility pole tube holding utility tubes and transformers as distributed centers.

Spherical and tubular guitar with cyclically vibrating tube-strings emanates omni-directional arrows of music.

Tubular blenny with clonons of scales forming border. Sheet like fins moving in cycles produce arrows of movement. Binaries of spherical eyes, appendages.

Great Wall of China creates border with pores and made of repeating clonons.

San Francisco Peaks in northern Arizona. Tubular road divides high desert field-sheet and emerge from the Colorado Plateau. They are one of the four centers or sacred mountains for the Navajo and Hopi.

Examples of Metapatterns and Chaos and Complexity Notions in Data Analysis and Design
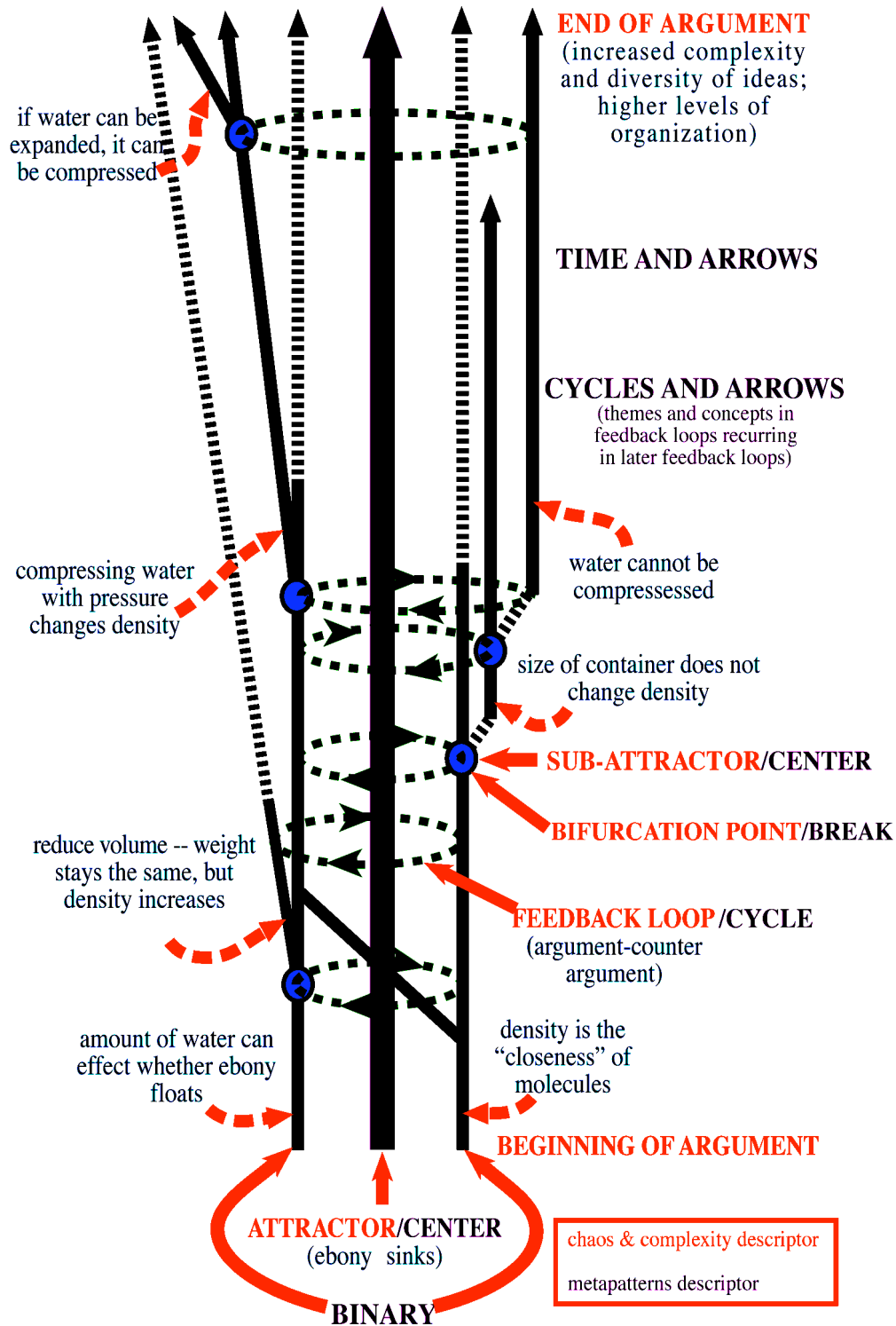
Figure E1. A chaos and complexity analysis of an extended student argument about density. Related metapatterns have been added in italics. Adapted from Bloom (2001).

The following figures appeared in:

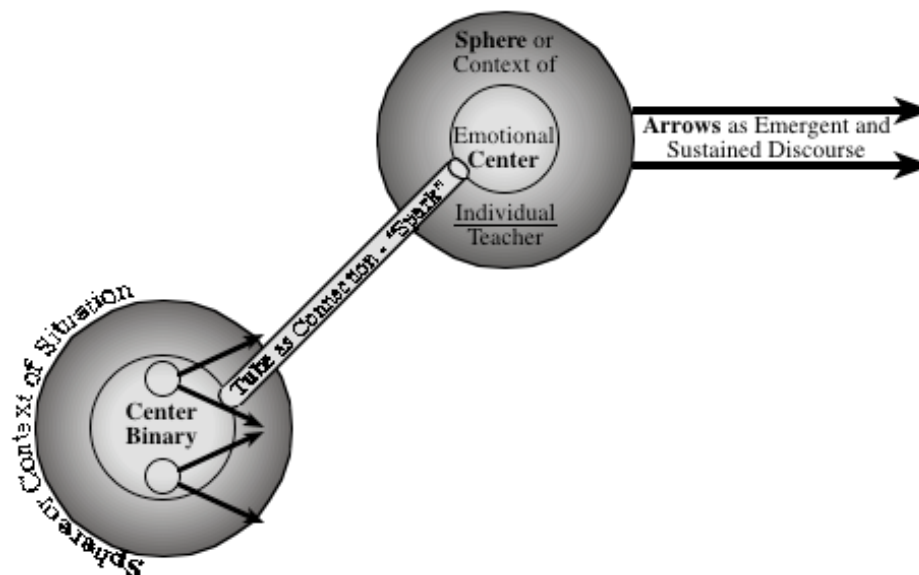Bloom, J. W. (2002). *Conflicts and concerns in an elementary teachers' science group: A metapatterns analysis of emergence, complexity, and issues of schooling.* A paper presented at the annual meeting of the American Educational Research Association, New Orleans, April.


Figure E2. Representation of necessary components and relations for emergent and sustained discourse.

Figure E2 was developed from analysis of elementary teachers' conversations during bimonthly meetings. Invariably, the meetings began with conversations about their work conditions and the state of schooling in their district. A number issues appearing as center-binaries (e.g., superintendent's push to teach more science through inquiry vs. his policies requiring vastly increased attention to raising test scores) struck emotion chords in the teachers, which in turn resulted in sustained discourse.
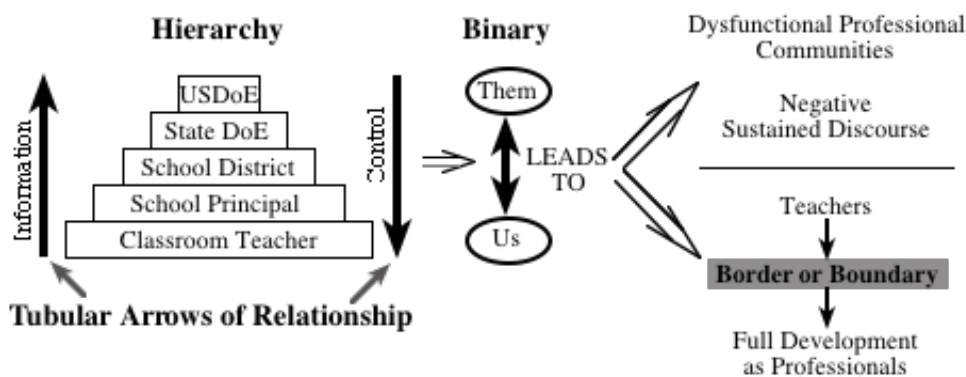
Figure E3. Hierarchical binary of schooling as basis for sustained teacher discourse.

As in figure E2, E3 represents the nature and establishment of many of the binary-based issues that arose during teachers' conversations. In this figure, the hierarchical nature of schooling tends to establish a disparate "us against them" binary, which in turn leads to dysfunctional professional communities and establishes a border or obstacle to professional development.
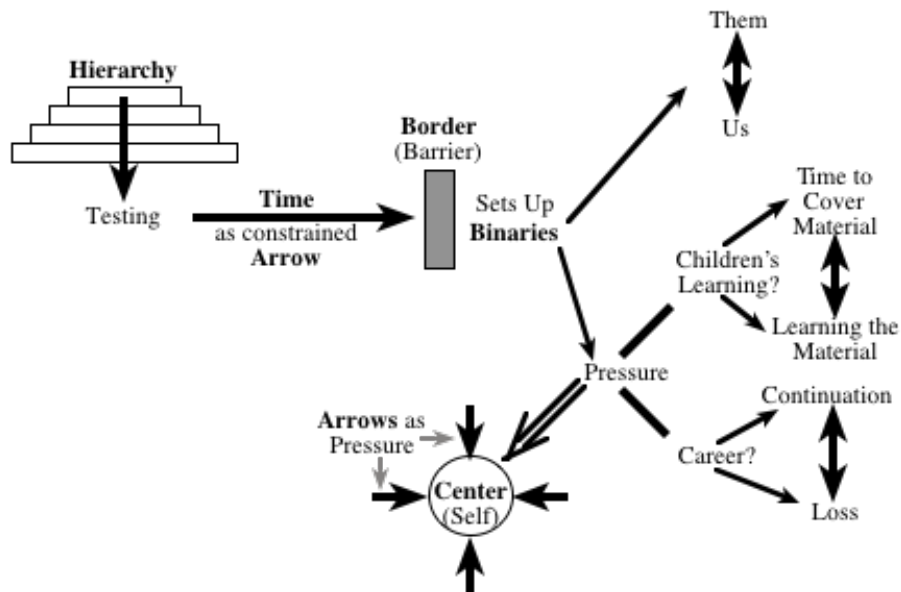
Figure E4. A representation of the hierarchical pressures of testing.

In figure E4, the context and affects of testing is represented with the political hierarchy of schooling and its mandating of testing setting up a border. This border creates a number of disparate, conflicting binaries, which create stressful pressures on both teachers and students as individuals.
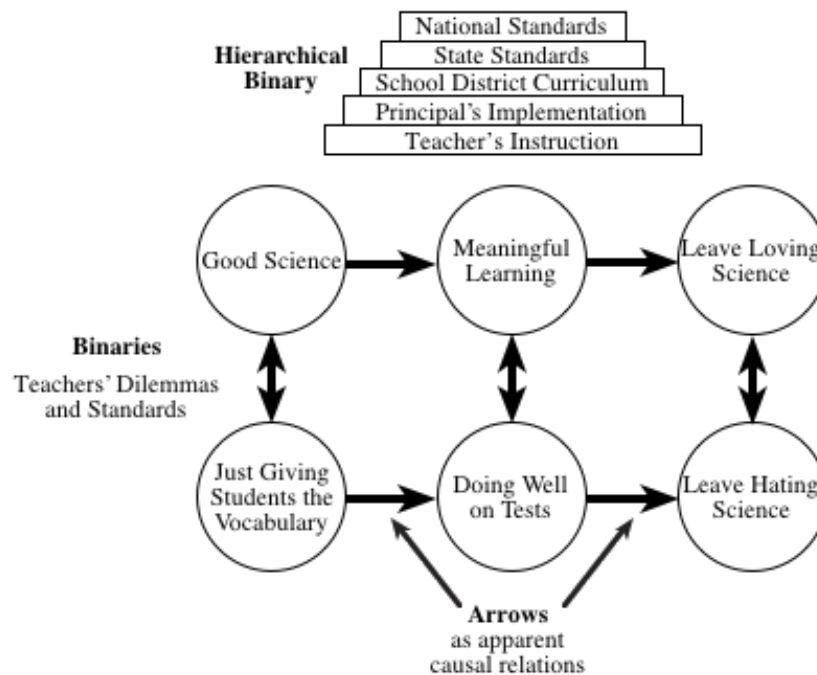
Figure E5. Standards as hierarchically created binaries with apparent causal relations.

Figure E5 depicts a number of binaries faced by teachers as dilemmas to their professional actions. Teachers saw these binaries in causal relationship to one another (depicted by the arrows). The terms used to describe these binaries are quotes extracted from teachers' conversations.

```
Teacher ——————— Efficiency          LEADS TO    Teacher "Satisfaction" *

Center          Time    Binary                  Superficial, Algorythmic
                                                 Understandings, At Best

                                                 Student (and Teacher)
                                                 Confidence
Student ——— Time to Struggle with Problem  LEADS TO
                                                 Complex, Integrated,
                                                 and Meaningful
                                                 Understandings
```

* "Teacher satisfaction" in the sense used here is a result of the hierarchical notions of schooling, which impose content coverage over meaningful learning, where satisfaction involves teachers feeling that they covered the required content.

Figure E6. Teacher (Barbara's) dilemma (binary) of time as binary in mathematical problem solving.

Figure E6 represents one teacher's description of an instructional event and her discussion of this event in the context of the typical expectations of schooling. She saw the teacher-student relationship (binary) along with a time binary (a binary of inherent vs. imposed needs) as the organizational center for continued actions. Her need to meet the imposed demands of schooling through efficient instruction is juxtaposed with the need of the child to struggle with problems (which is a time-consuming process). Although she felt that her meeting of imposed needs made her feel "satisfied" with her achievements, real learning only occurred by addressing the more time-consuming needs of students.
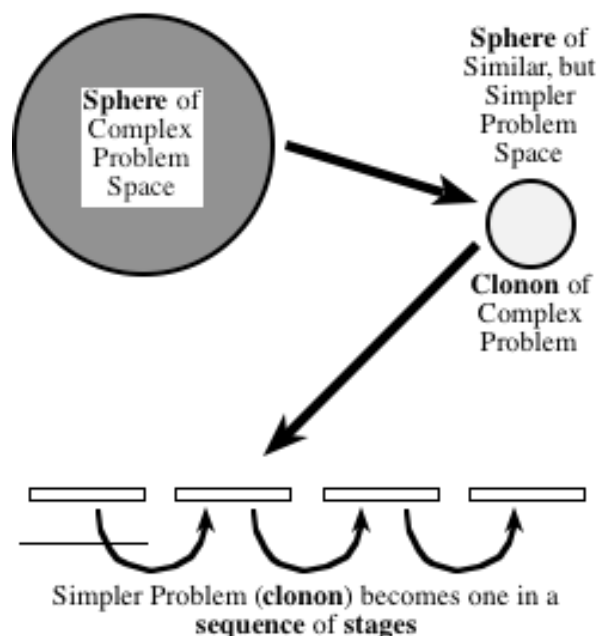
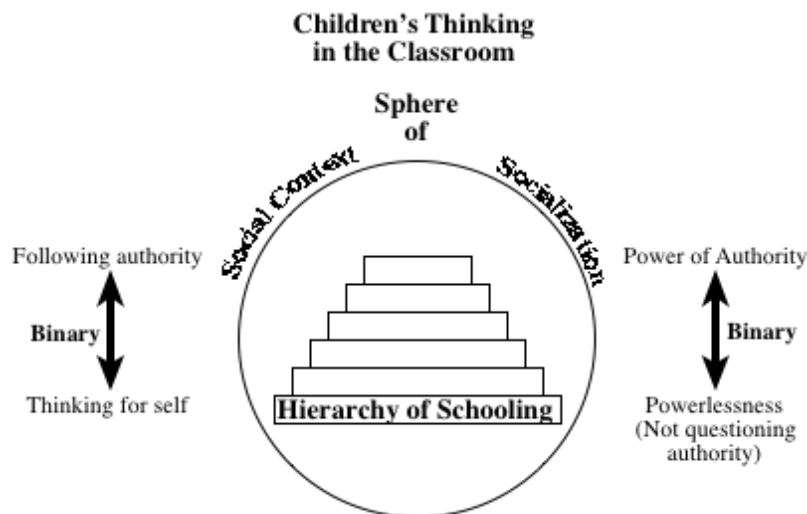*Figure E7.* Teacher (George's) approach to teaching mathematics as layered (use of clonon or simpler versions of complex problem) sequence of stages.

In figure E7, one teacher saw his approach to helping student solve problems was one of sequential layering, where complex problems were broken down into sequences of repetitive steps (i.e., clonons of steps making up the holon of the problem space).
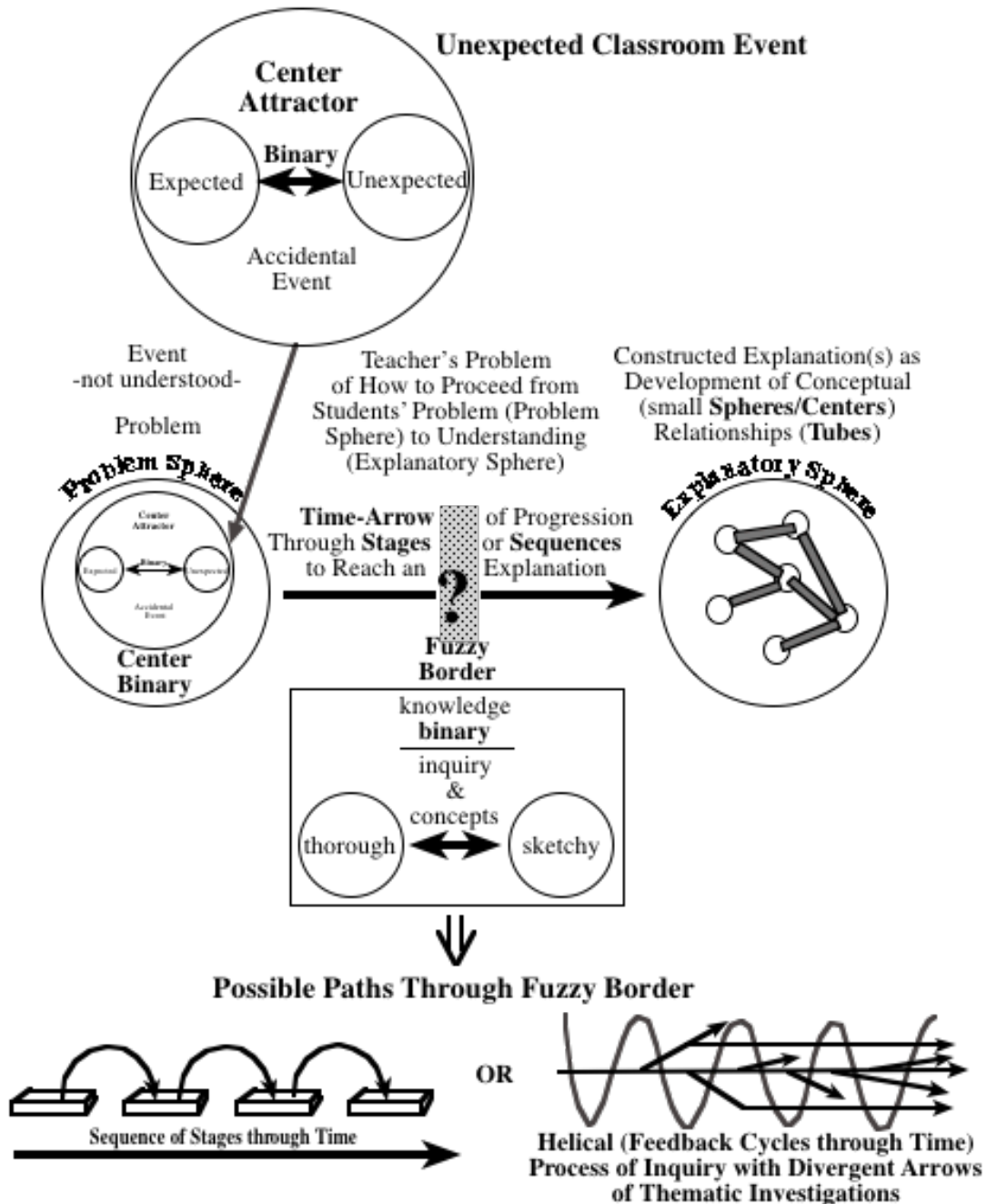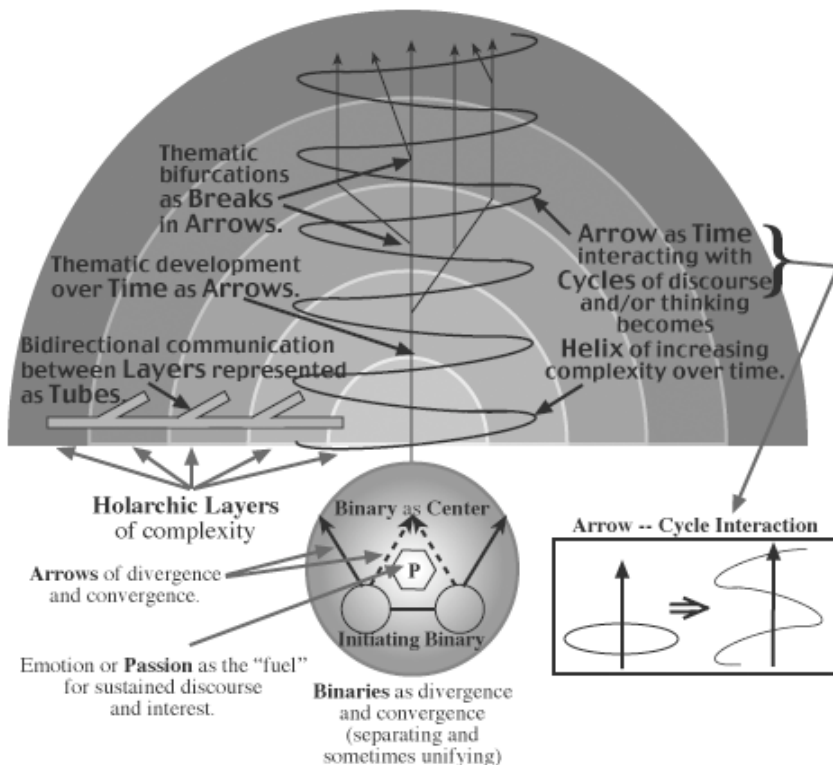
Figure E8. Unexpected events during children's inquiry and teacher's problem of how to proceed.

Figure E8 depicts a more complex model of the kind of event shown in figure E7. The center (attractor) is comprised of a binary between what is expected vs. the unexpected. This binary becomes the center of a problem sphere. Proceeding from the problem sphere to a solution and an explanatory sphere encounters a border comprised of cognitive binaries consisting of thorough vs. sketchy knowledge and expertise in inquiry. Progression past this border can consist of a sequence of stages or of a helical process including interactions between feedback cycles and thematic arrows of progression that diverge (breaks or transformations) creating increasingly complex understandings and explanations.
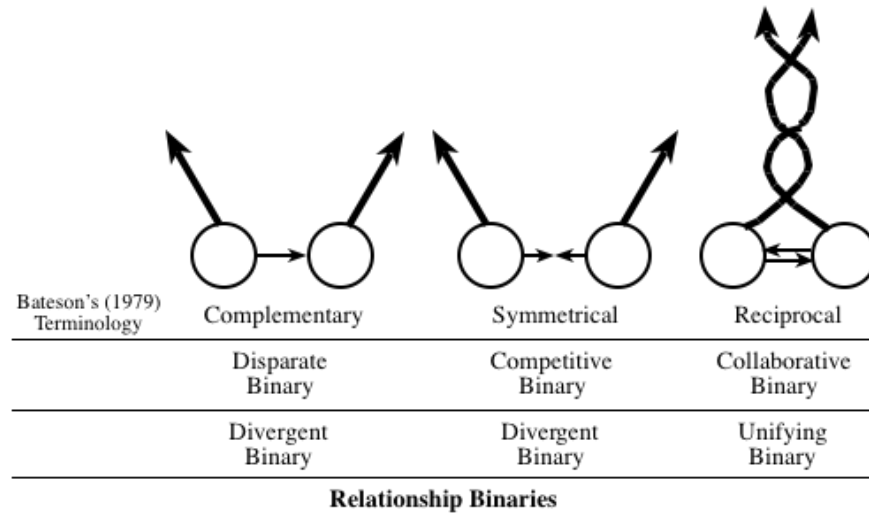
**Children's Thinking
in the Classroom**

**Sphere
of**

Social Context   *Socialization*

Following authority

Binary

Thinking for self

Power of Authority

Binary

Powerlessness
(Not questioning
authority)

Hierarchy of Schooling

Figure E9. Teachers' perceptions of how children's thinking for themselves is prevented by their socialization in a schooling hierarchy, in which children defer to authority.

Figure E9 depicts another set of binary conflicts established by the social context of the hierarchy of schooling. For students, these binaries include following authority vs. thinking for oneself, which is related to the binary of authoritarian power vs. a feeling of powerlessness.

Thematic
bifurcations
as Breaks
in Arrows.

Thematic development
over Time as Arrows.

Bidirectional communication
between Layers represented
as Tubes.

Arrow as Time
interacting with
Cycles of discourse
and/or thinking
becomes
Helix of increasing
complexity over time.

Holarchic Layers
of complexity

Arrows of divergence
and convergence.

Emotion or **Passion** as the "fuel"
for sustained discourse
and interest.

Binary as Center

P

Initiating Binary

Binaries as divergence
and convergence
(separating and
sometimes unifying)

Arrow -- Cycle Interaction

Figure E10. A generalized model of sustained teacher interactions using metapatterns.

Figure E10 depicts of a model of the context for sustained teacher interactions. This model includes "passion" as the energy that drives the binary-based emergence of such a complex system of cognition, discourse, and action.

Bateson's (1979) Terminology	Complementary	Symmetrical	Reciprocal
	Disparate Binary	Competitive Binary	Collaborative Binary
	Divergent Binary	Divergent Binary	Unifying Binary

Relationship Binaries

*Figure E11.* Bateson's three types of relationship as types of binaries.

In figure E11, Bateson's three types of relationships are represented as divergent and convergent binaries.
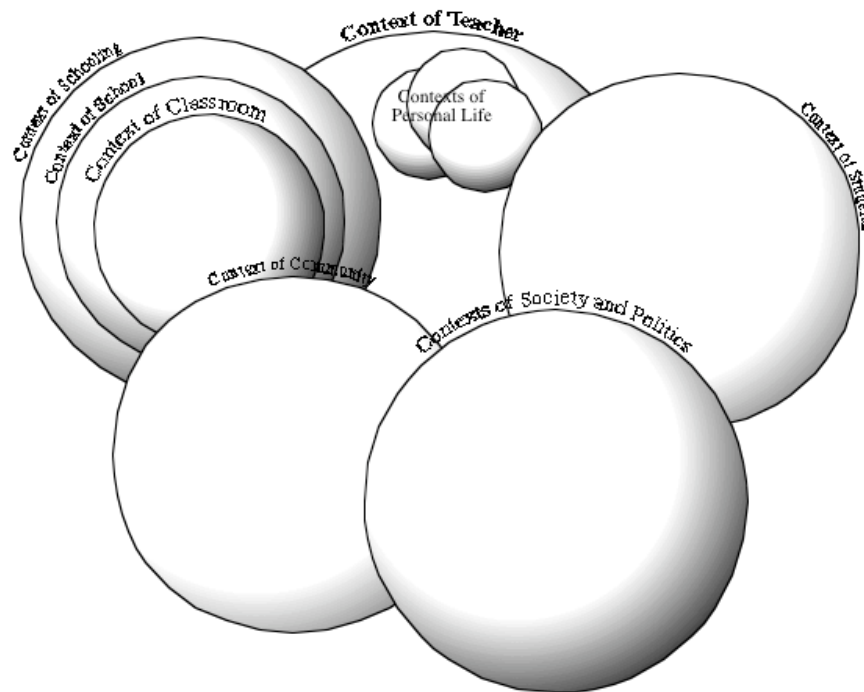
Figure E12. A representation of the contexts affecting teachers' lives and discourse.

Figure E12 provides a simple representation of the context of teachers' lives and discourse. This "meta-context" contains numerous other contexts that affect and contribute to the whole the teacher. All of these contexts constitute the teacher and how he or she manifests in the profession.
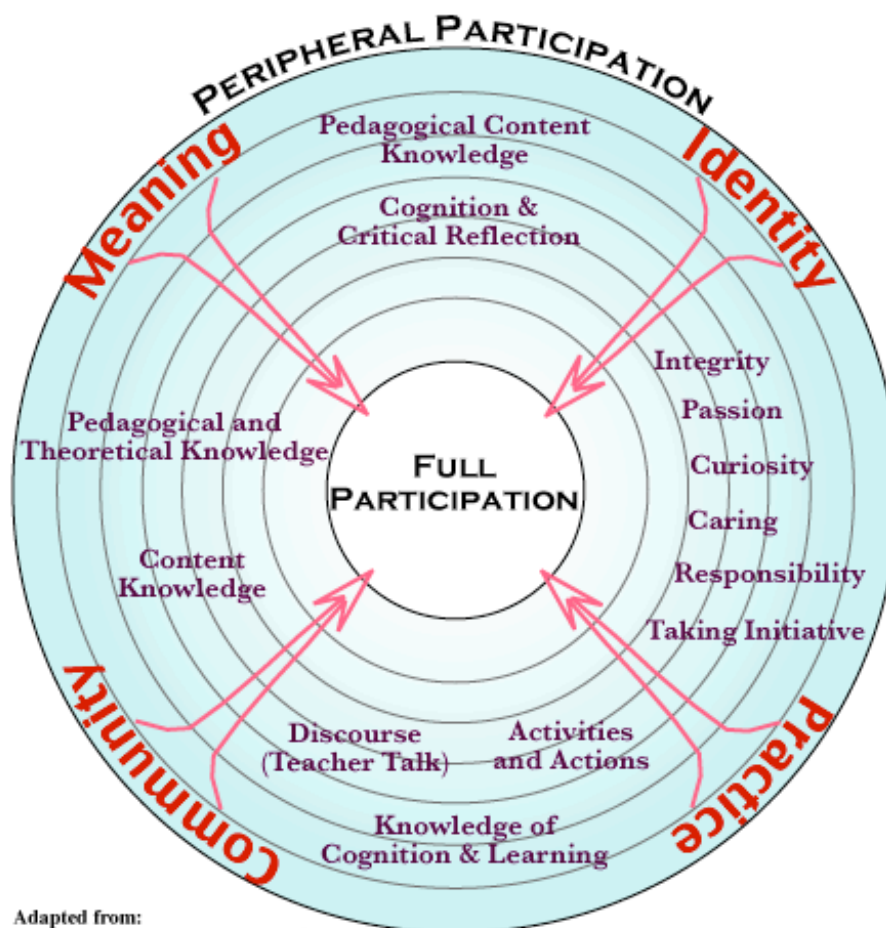
Figure E13. Elements of a professional community of teachers as holarchy (based on Wenger's [1998] notion of communities of practice).

Figure E13 utilizes the notion of holarchy as a design tool for describing the community of teaching. From the periphery to the center of full participation, people entering the profession move through layers of increasing complexity in identity, meaning, practice, and understandings of community.

38

The following figures appear in:
Bloom, J. W. (2003). *Entering the community of teachers: The difficulties and prospects in raising the bar of expectations in an elementary science methods course.* A paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, March.
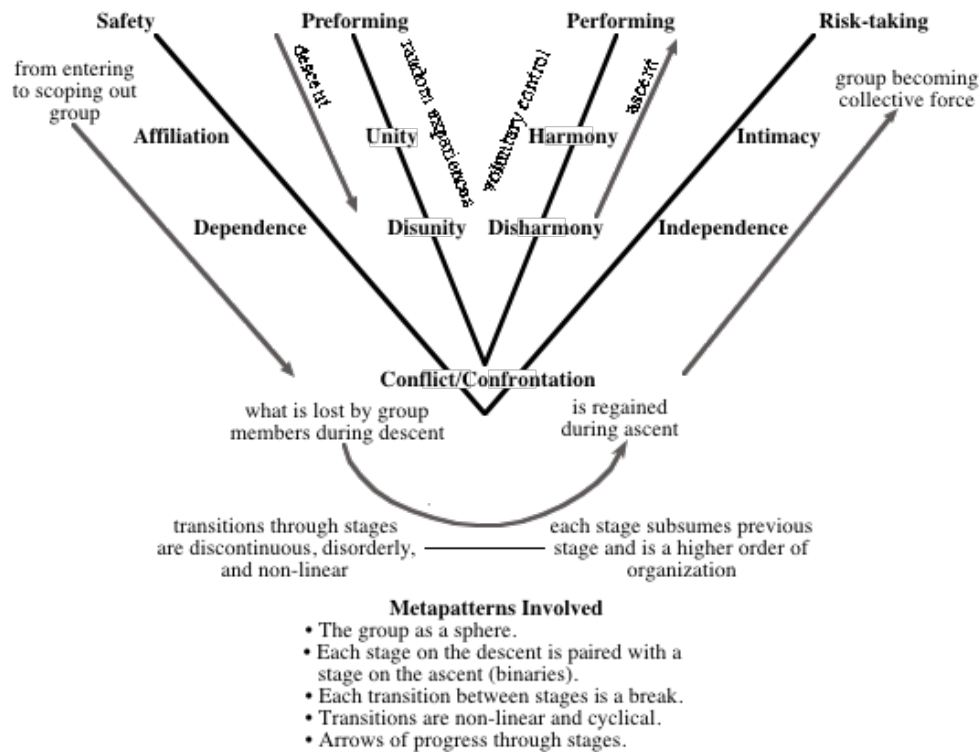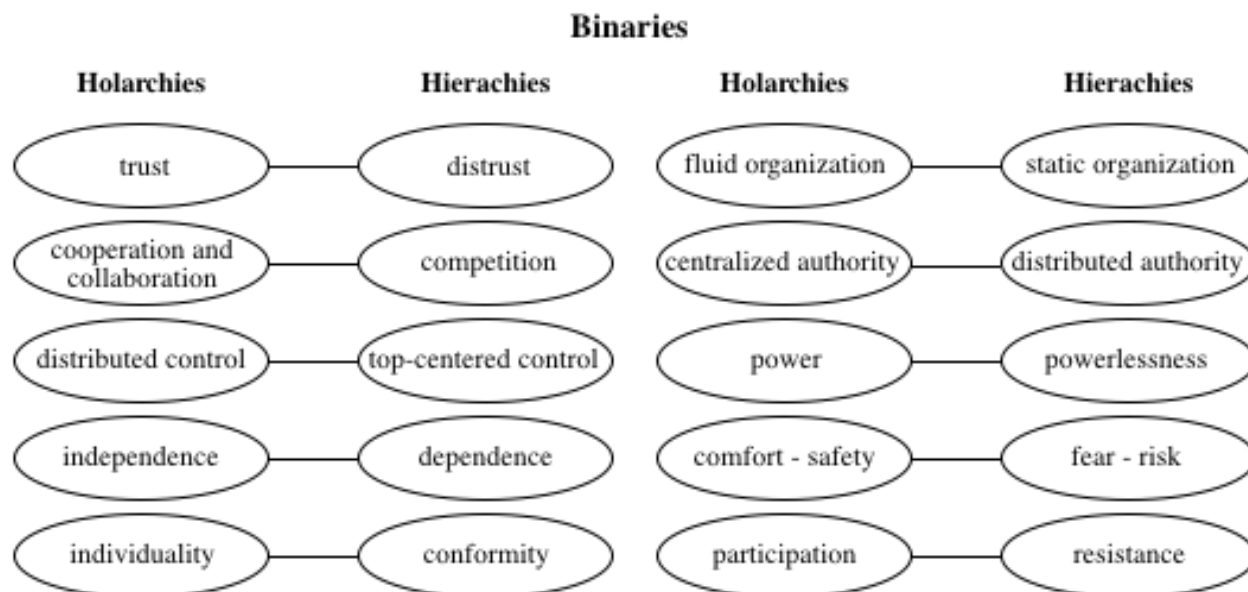

Figure E14. Adaptation of McClure's (1998, p. 50) model (arc) of stages of group development with associated issues, as well as associated metapatterns.
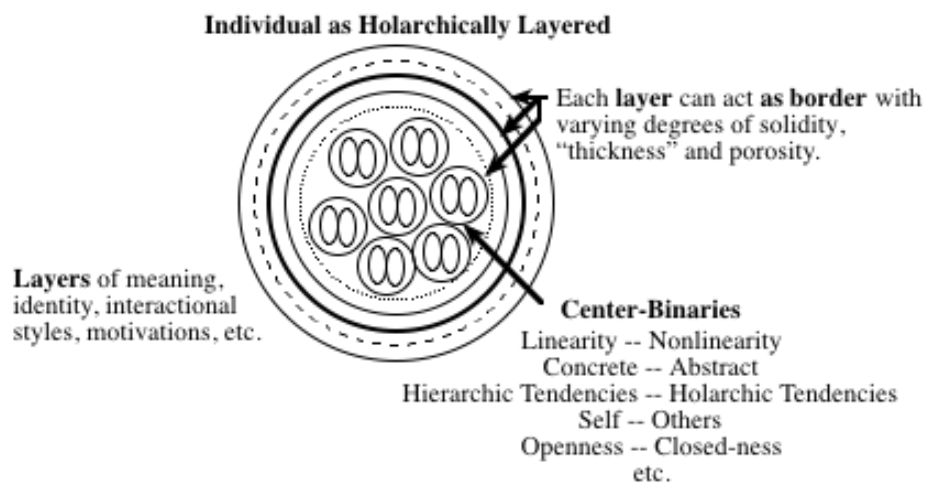

Figure E15. Notion of individual as holarchy.

Figure E15 describes how we may be able to describe individuals as layered with a variety binary-based centers.

Binaries

Holarchies	Hierachies	Holarchies	Hierachies
trust	distrust	fluid organization	static organization
cooperation and collaboration	competition	centralized authority	distributed authority
distributed control	top-centered control	power	powerlessness
independence	dependence	comfort - safety	fear - risk
individuality	conformity	participation	resistance

Figure E16. Common binaries evident when comparing holarchic and hierarchic situations.

Figure E16 depicts some of the common characteristics of hierarchies and holarchies as they manifest in social institutions. Corresponding characteristics across the hierarchy-holarchy division are represented as binaries.
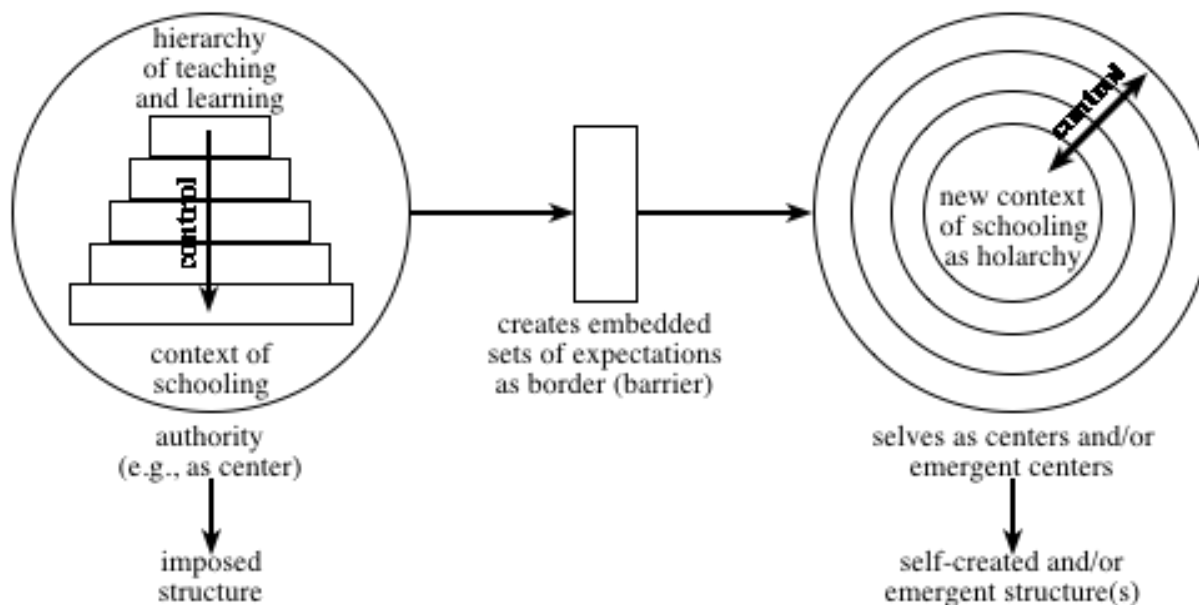
Figure E17. The creation of a barrier in moving from a hierarchic to holarchic approach to induction to a community of professionals.

Figure E17 and E18 portray differences between schooling as hierarchic and as holarchic. The differences include hierarchies as authority centered with imposed structures vs. holarchies as individual centered with emergent structures. The differences in such characteristics result in the tendencies to create separating binaries in hierachies and unifying binaries in holarchies.
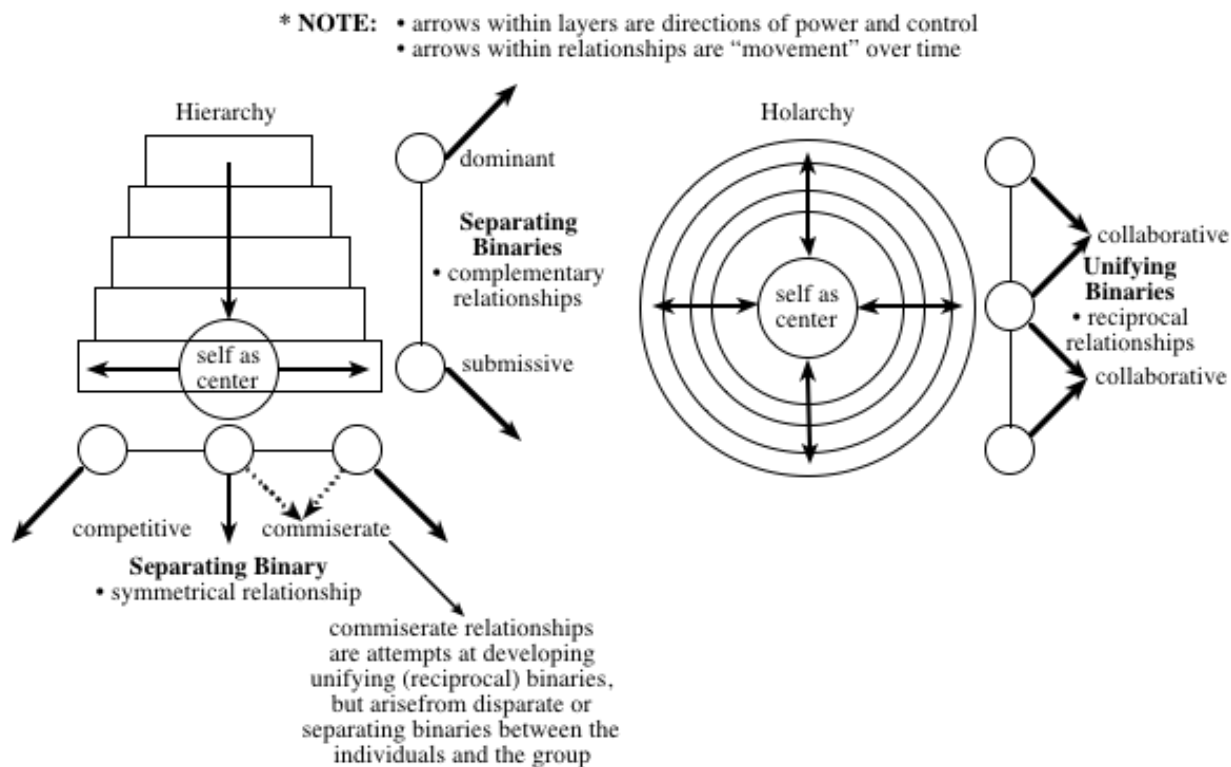
Figure E18. Binaries established by hierarchies and holarchies in terms of the individual and his or her social interactions and relationships.
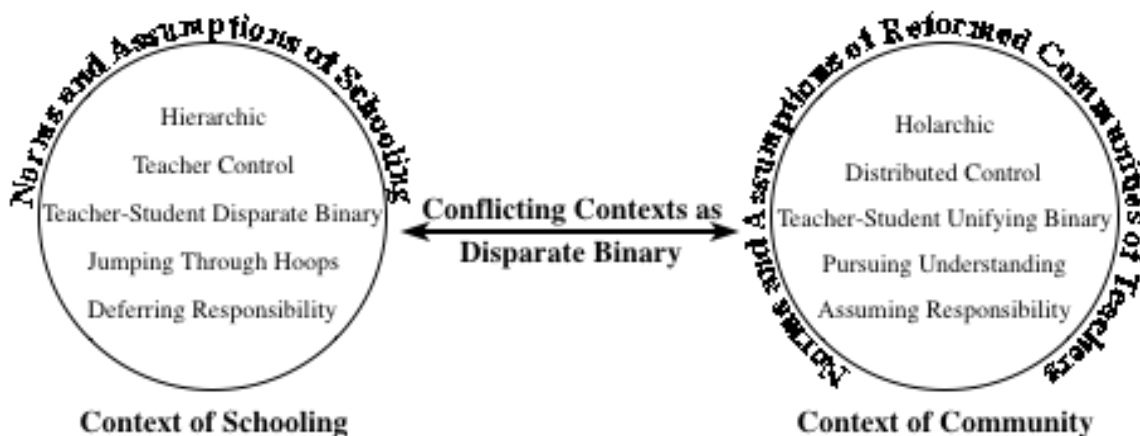

Figure E19. The contexts of schooling and professional communities as a conflicting binary.

Figure E19 was generated from analyses of education students' participation (and lack of participation) in an elementary science methods course along with an overall analysis of the underlying assumptions of schooling, in general. The context of schooling, which is characteristically hierarchic, establishes sets of assumptions that are not conducive to participation in professional communities as suggested by Etienne Wenger (1998). Such a disparate binary of between these two contexts creates significant challenges for teacher educators who attempt to prepare students to take on the roles of self-sufficient and collaborative professionals.

Table E1. Assumptions and expectations in hierarchies and holarchies.

Layered Organization	Assumptions	Expectations
		LEVEL
Hierarchy		**Top**
	• Static top down organization • Control centered at top and moves down • Ownership centered at top • Control acquired competitively • Competition valued • Deference of power to higher layers • Identity based on layer (controlling or controlled) • Meaning situated in complex relations among position in layer, rewards, control, power, etc. • Induction is imposed upon inductees from higher levels • Degree of participation is imposed	• Those at lower levels not to be trusted • Obedience to authority • Use of strategies for control and power • Formulate rules • Set expectations of behavior, etc.
		Bottom
		• Those at higher levels not to be trusted (or blindly trusted) • Obedience to authorities • Defer control and power to those at higher levels • Follow rules • Conform to expectations of behavior, etc.
Holarchy		**Full**
	• Fluid, distributed organization among participants • Control distributed among participants • Ownership distributed among participants • Control acquired with increased participation • Cooperation and collaboration valued • Shared power • Identity based on participation • Meaning situated in complex relations among participation, identity as participant, etc. • Induction is socially-mediated • Degree of participation is self-determined within social sphere	• New, peripheral participants move toward full participation • Question authority of self and others • Collaborate on and negotiate the formulation of rules, expectations, etc. • Assume responsibility and expect others to assume responsibility
		Peripheral
		• New participants determine degrees and approaches to participation • Question authority of self and others • Collaborate on and negotiate the formulation of rules, expectations, etc. • Work towards assuming responsibility and expect others to assume responsibility

Table E1 delineates the differences between hierarchies and holarchies in social situations and institutions. In analyzing and/or designing social groupings of various sorts, knowledge of such differences in assumptions, expectations, and characteristics are essential in creating consistent and cohesive environments.

42
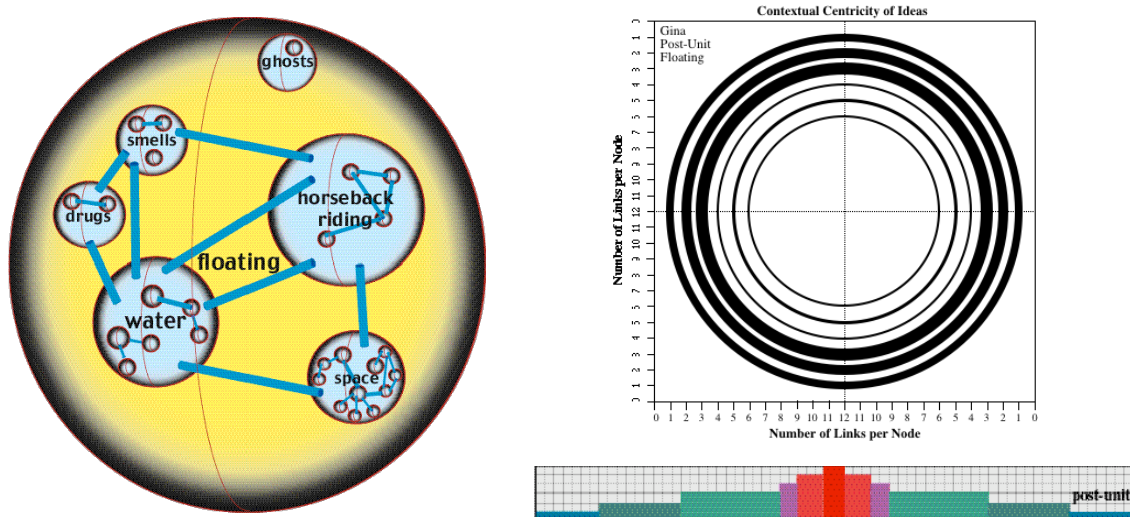
***Figure E20*. TOP**: A context map on floating completed by a grade 7 girl after a unit on floating. **BOTTOM LEFT.** Diagram representing nodal centricity (i.e., how many links at each node) on the post-unit map. [<u>NOTE</u>: Line thickness corresponds to the number of nodes.] **MIDDLE RIGHT:** Metapattern representations of Gina's post-unit floating context map. [<u>NOTE</u>: Embedded spheres and tubes of relations.] **BOTTOM RIGHT**: Another representation of centricity on the post-unit context map. Here the vertical dimension represents the number of links per node (range = 1 to 6) and the horizontal dimension the number of nodes (range = 1 to 12). With the exception of the central vertical bar, the right and left sides are mirrored in order to capture the sense of centrality and breadth.

Figure E21. A grade 5 boy's explanation of life on Earth task showing extensive use of binaries.
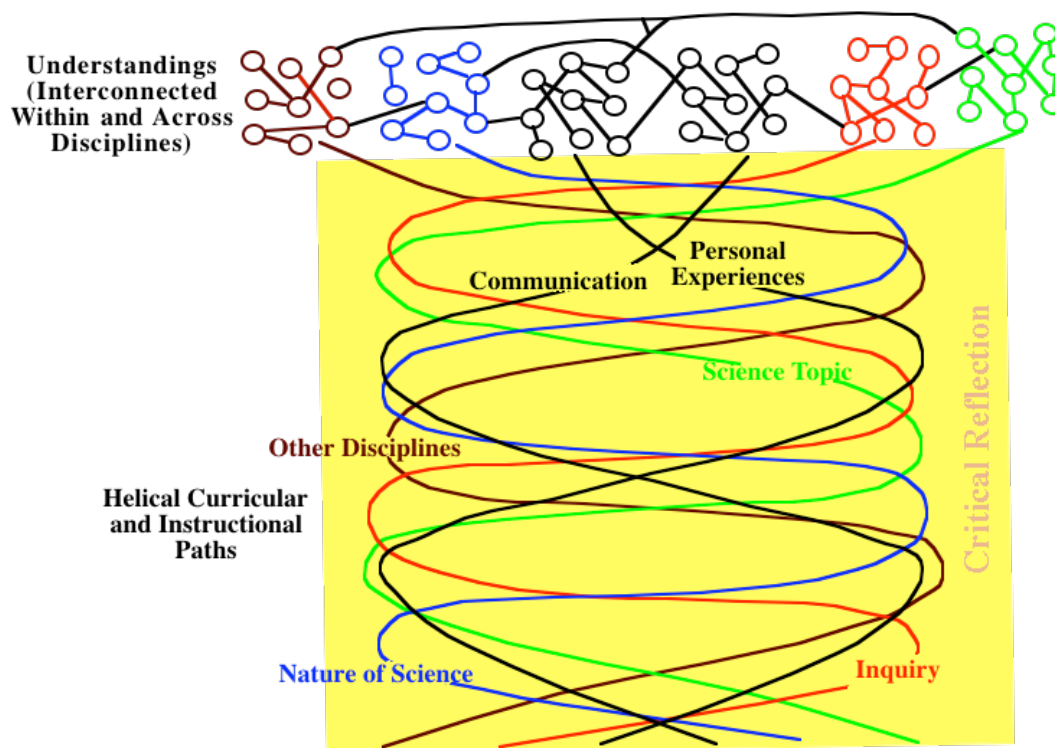
Figure E22. A "patterns that connect" curricular model that is supportive of a metapattern and chaos and complexity approach. Here, curricular implementation is represented as arrows of time creating interconnecting helices from cycles of inquiry arising from a common problem-based center. The resulting sphere of knowledge and understanding is comprised of richly interconnected sub-spheres and centers of knowledge (tubes-sphere-centers).

The following figure appeared in:

Bloom, J. W. (2000, April). *Chaos, complexity, and patterns that connect.* Focus symposium for the Chaos and Complexity Special Interest Group at the annual meeting of the American Educational Research Association, New Orleans.
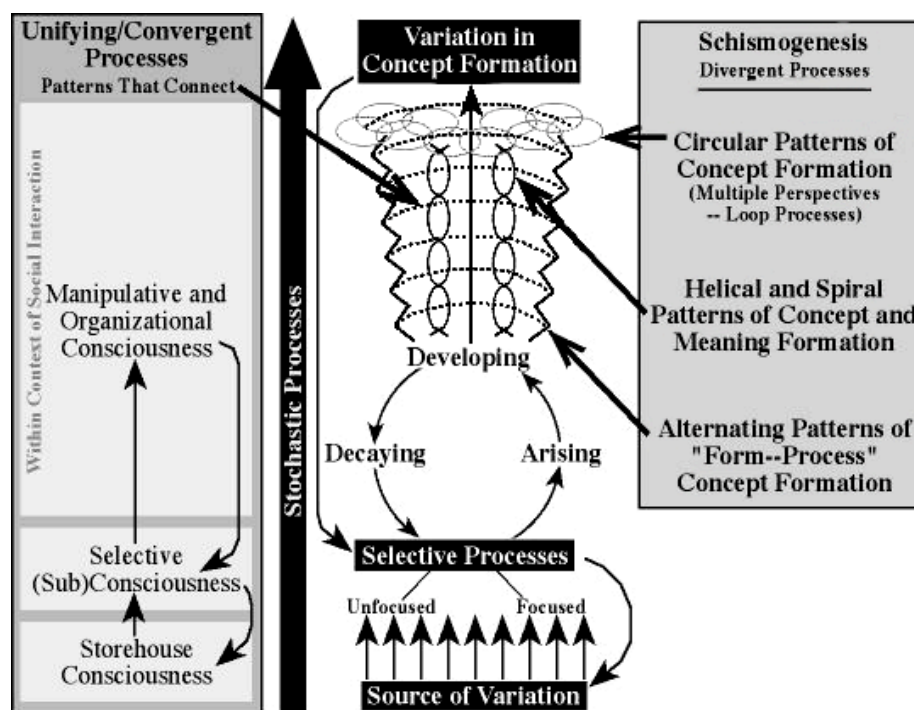
- **Learning begins from a basis of random variation and moves towards:**
  - ➔ greater complexity along recursive paths
  - ➔ levels of knowing
  - ➔ patterns that connect
- At bottom, **eighth level of conscious** (Buddhist notion)
  - ➔ proceeding to the **sixth level of consciousness** (most of top half of diagram)
- Above the circular cycle of arising, developing, and decaying thoughts, are:
  - the general processes of **knowledge construction,** including:
    - **alternating sequences of form and process**
    - **helical and spiral patterns of concept formation**
    - **multiple perspectives--loop processes**
    - **circular patterns of concept formation**
- **"Patterns that connect"** appear as:
  - arcs crossing between the form-process sequences and helical patterns
  - points connecting the spirals of the helices
  - connecting lines in the multiple perspectives--loop processes.
- **Multiple perspectives--loop processes** (the shaded circular shapes) represent specific perspectives, concepts, or understandings.
- Lines between these circular shapes, helical patterns, and form--process sequences represent conceptual links or **Patterns That Connect.**

Figure E23. A model of consciousness based on chaos theory, evolutionary biology, and Buddhist psychology.

PART III
Sample Data Sets

Sample Data Sets for Potential Analysis

Data Set #1: May 5, 1988 – Grade 1/2 – Grade 1 Boy's Interview on Animals

JB. now we can do something
I. I think this one's amazing
JB. do you know what that is?
I. looks like its sponge
JB. uh huh
I. 'cause it looks just like one [OC]
I. this I know is sponge cause it looks like sponge and it feels like it
JB. uh huh what is a sponge?
I. a sponge is something that you'd use in the bathtub to scrub yourself
JB. oh right what else do you know about sponges
I. that you can wash dishes with them and and and they can be really nice when they are swaying in the water they can be really beautiful
JB. uh huh
I. do you know how I know that cause my my aunt and uncle are scuba divers
JB. oh really so they've seen sponges
I. so they've seen these things wading along in the water
JB. are they alive?
I. they are
JB. uh huh
I. when they are underwater they are
JB. yeah are they a plant or an animal do you know?
I. they are an animal a sea urchin
JB. yeah? interesting
I. this one's a little bit broken there
JB. yeah it looks like its been torn it apart a little bit
I. well someone tore it apart a little bit look at this a little fish
JB. uh huh
I. what kind of fish is this?
JB. I think he's called a trunkfish
I. I know that it hides in the sand because its kind of sandy and sparkly like sand and it looks a little bit like sand
JB. uh huh
I. it's easy to see the sparkles
JB. yeah
I. so that it can hide in the sand
JB. right
I. a kid catched catched some meat to eat
JB. uh huh neat wow
I. I know a lot about snakes
JB. you do well let's take a look at this snake what do you tell me what you know about snakes

I.   that they're very gentle animals except if you pick them up or touch them they won't be very nice

JB. uh huh

I.   I know that because I used to get a bucket of snakes of them a day

JB. you did

I.   I used to catch snakes

JB. really wow these kind of snakes?

I.   no garter (sic) snakes

JB. uh huh

I.   but any kind of snake if you touch it it will bite you and very much hurt you

JB. uh huh

I.   you can bleed

JB. uh huh

I.   do you know what? if this if this mouth wasn't too fragile you could just [...] right through [...] see the teeth

JB. uh huh

I.   I know that the teeth are very sharp

JB. yeah yep

I.   and

JB.   what do they eat?

I.   and this

JB. what do snakes eat?

I.   I know is coral

JB. you do what's coral

I.   coral is another sea creature

JB. uh huh

I.   just like the sponge

JB. uh huh

I.   and it works kind of the same way

JB. uh huh

I.   it sprays just the same way and it looks just the same while it while they're underwater

JB. yes

I.   but this one's a lot holier

JB. which one the coral's holier?

I.   yeah

JB. yeah what are the holes for?

I.   I think it's for breathing

JB. for breathing?

I.   sucking the air in then a another one would push it out

JB. uh huh

I.   and then and then all the air would would stay in while the water starts squishing out

JB. uh huh

I.   that's the same as a fish

JB. mm hmm

I.   well this one it soaks in the water and then and then and then it squeezes together and then the water comes out with the airs

JB. **uh huh**
I. but the but but the air stays in
JB. **uh huh**
I. it's just like when you put the sponge in the water
JB. **right**
I. it will grow alive again
JB. **really? oh**
I. and that's I think that might be the same with coral
JB. **really interesting I might try that out sometime**
I. I know this this is a kind of rock but it's a very special rock you know why
JB. **why?**
I. you can see see right there
JB. **right**
I. that's some [...] some kind of fish and that's another one
JB. **uh huh interesting**
I.   and that's
JB. **how did they get there?**
I. I don't know there's hundreds of them on this
JB. **yeah**
I. but its really beautiful inside
JB. **yeah [...]**
I. do you know what? someone could probably make a floor out of this you see those colors in there?
JB. **oh yeah**
I. that's the same colors of the floor
JB. **of the floor yeah of the tile yeah it is**
I. do you see?
JB. **that's neat interesting**
I. they must have made that floor out of this kind of rock
JB. **huh maybe**
I. maybe look at this
JB. **uh huh somebody wrote on it**
I. somebody a scuba diver must have wrote on it with their waterproof pen
JB. **yeah that's funny let's see what else have we got here?**
I. what is this?
JB. **that's a magnifier if you want to look at something close up do you want to look at that**
I. okay
JB. **do you know what this stuff is?**
I. what's this for?
JB. **that's here I'll just put that here like this and you can look through one or both or hmm**
I. I'm going to look at that [..] there it should look a lot better with two it should look a lot better
JB. **mm hmm**
I. [...] I can see it even its gills

JB. **you can see the gills on that little tiny one aah that's neat**
I.   do see that one it looks a lot bigger
JB. **uh huh**
I.   the gills are really small
JB. **uh huh if you look at this side probably we could see a mouse**
I.   I can see it its just a little dot
JB. **really for a mouse what does he eat? if it's a little dot for a mouse**
I.   I think it would eat those floating kind of minerals
JB. **uh huh**
I.   that whale's eat
JB. **uh huh its possible it's possible do you know what those other things are in here? do you know what these guys are?**
I.   that's that's a big minnow that's a sea horse just let me look at this looks like that's a flat stingray
JB. **it does doesn't it (laughs)**
I.   because its flat (laughs) it is a stingray
JB. **do you think so? how can you tell?**
I.   it just got killed
JB. **uh huh**
I.   and flattened even you can notice on the back where it got killed
JB. **uh huh yeah the red spot**
I.   and then it got flattened like this the big one I can notice is flattened and killed too
JB. **yeah**
I.   this one I can just tell its not flat and not killed
JB. **uh huh**
I.   it just died because of being out of the water
JB. **right**
I.   what could this be?
JB. **beats me**
I.   I think its another piece of coral there's different kinds
JB. **uh huh**
I.   probably
JB. **this looks a lot different it's got all these spookies on it**
I.   yeah but it has to be a coral
JB. **uh huh**
I.   how could this snail get this
JB. **I don't know**
I.   might not be a snail maybe a shrimp
JB. **looks like well yeah it looks like a snail it looks like a shrimp too**
I.   might be a shrimp you know people sometimes just chip off this and just bake it in the oven
JB. **uh huh**
I.   probably that's how it turns to shrimp maybe this is shrimp
JB. **huh**
I.   look at the shell here I'm going to look at this potato chip (laughs) cause it looks like a potato chip
JB. **yeah ruffled or ridgy or whatever they call them**

I.   I'm just going to look at it a little better here aah its really pretty that's blue that white stuff is blue

JB.   uh huh

I.   and the other is white and brown

JB.   uh huh

I.   but you can even see it out here

JB.   yeah but the white stuff looks blue when you look at it close

I.   I'm going to look at this one close hey I can tell this was I think it was a clam a baby clam can't you see?

JB.   yeah

I.   that looks like the hinges on a baby clam

JB.   it does doesn't it

I.   shell

JB.   it sure does huh that's nice

I.   look at this I know what this is

JB.   what is that?

I.   a snail shell can't you see?

JB.   uh huh

I.   the snail's body is rrrrrit the snail really is really long

JB.   uh huh

I.   so long that it goes rrrrit and out

JB.   out the other end

I.   out there and then and then it would scream along the back pushing it along

JB.   uh huh

I.   and the front pushing it along

JB.   huh that's neat

I.   snail bodies are very very long

JB.   uh huh

I.   I know what these are crayfish I caught a crayfish once

JB.   you did he pinch you?

I.   I caught one quite fast he didn't pinch me

JB.   uh what are these other things up here?

I.   do you know how I caught it?

JB.   how

I.   you just take a paddle and you put it in front of you and the crayfish gets very very scared and (OC)

JB.   yeah

I.   and then and then you put the net behind it

JB.   uh huh

I.   and you know there's discs there's the paddle when he gets scared so he walks backwards

JB.   and he walks into your net?

I.   yep

JB.   that's pretty tricky

I.   he walks right into the net

JB.   tricky tricky look at this small

I.   let's look at this

JB. **okay go ahead**
I.   I know about starfishes too starfishes do you know what?
JB. **uh huh**
I.   those things on the bottom are really legs
JB. **really**
I.   and right in there is where they would swallow their food too
JB. **in the middle so where show me the legs again show me the legs again? which are the legs?**
I.   the legs are those white things
JB. **the white things in there**
I.   yeah and if the food gets away they just grab it in there and it would go rrraa
JB. **[...]**
I.   right into his mouth
JB. **uh huh interesting**
I.   and do you know what that's the mouth and this one is one that's that is broken open right there there and there
JB. **uh huh**
I.   you see it's different from that
JB. **right**
I.   and it looks like it's going in
JB. yep
I.   and you can kind of see well I can see if its turning but all of the food has sort formed into a gold pearl see?
JB. **you think so? really it does look like a little gold pearl**
I.   it is it turned from food into a gold pearl
JB. **really**
I.   can you believe it? [...]
JB. **what about this these guys?**
I.   oh this and this are starfishes too
JB. **mm hmm**
I.   different kinds
JB. **do you know what the other guys are?**
I.   this one's a dead fish cause you can see inside it
JB. **uh huh**
I.   and that's something I don't know what its called
JB. **uh huh**
I.   this is probably a piece of coral
JB. **what's the red stuff?**
I.   the red stuff is probably to hide it around so that and also in there when um something that that eats it comes along and slips underneath it it can just suck it up those holes
JB. **aah**
I.   or if it comes along over top it can just suck it up those holes
JB. **uh huh I see I see**
I.   and the [...] protect it protect it from from germs
JB. **aah I gotch ya**
I.   because fishes can get sick

JB. **they can**
I. that's why before you eat a fish you have to make sure that it's not sick
JB. **what's that?**
I. here is a kind of water worm
JB. **uh huh**
I. no its one of the glowing the dark worms that goes in caves
JB. **oh I see yeah that kind of clear**
I. yeah
JB. **mm hmm**
I. [...] no this is a frog's bones
JB. **that's a frog**
I. that's a frog this must be the minnow (laughs)
JB. **so what's how many of these are animals?**
I. I this this one this one this one
JB. **kay let's see we've got this wormy thing here the frog**
I. all of them
JB. **all of them are animals?**
I. except this one and this one
JB. **and that one that looks like a snail and that other one that looked like uh**
I. a clam
JB. **a clam**
I. because that's the little hinges
JB. **so a clam is not an animal?**
I. clams aren't animals cause do you know why?
JB. **why?**
I. if you look inside their shell all there is is a bod- is the insides
JB. **uh huh uh huh that's interesting what how can you tell an animal is an animal what makes an animal an animal?**
I. because an animal has skin
JB. **uh huh**
I. and this and the clear doesn't have skin inside
JB. **uh huh**
I. and this it doesn't move around because it's kind of a rock
JB. **oh right and uh these guys these crayfish are animals?**
I. yep everything else is an animal even this
JB. **even the sponge**
I. is an animal
JB. **uh huh how did you know a lot about this stuff?**
I. I found the piece
JB. **oh there was a piece stuck inside how about that**
I. a piece
JB. **[...]**
I. you did
JB. **oh it fits right**
I. it fits right in
JB. **okay**

I.   now its all set

JB. now it's all good again thanks a lot for coming by

I.   I know most about these creatures

JB.   are you in how old are you

I.   I'm seven

JB.   you're seven well that's neat

I.   I know about these things because I've seen them all except this fish

JB.   yeah

I.   can you see the gills on this?

JB.   I think so can you?

I.   right there

JB.   yeah you're right

I.   on the other side too he wants to hide his gills so that the fish can't see his gills so that so that the kind of thing doesn't see his gills and doesn't so so that it doesn't get seen

JB.   yeah what are gills what are his gills for?

I.   puffing out the water and and the air would stay inside him

JB.   uh huh that's neat do we have gills? do we have gills?

I.   no because because we don't live in the water

JB.   ah I see what do we have?

I.   but we swim in the water

JB.   yeah

I.   but when we swim in the water do you know what if we go out deep and we have to stan- stand in the water for a long time we use a scuba diving suit

JB.   suit right

I.   did you hear of a special rock that's got Indian paintings on them?

JB.   I've heard of them have you heard of them?

I.   I've heard of it and I've even see it seen it

JB.   where did you see it?

I.   I've see seen it in my canoe

JB.   in your canoe?

I.   we canoe down there

JB.   wow

I.   it's very far away it's in Trenton

JB.   uh huh oh that's neat I'll have to go look sometime

I.   and you have to go through through through a little st- pond type thing

JB.   uh huh

I.   but but it has very good finish- fishin' in that pool

JB.   uh huh

I.   and you can catch frogs at the start and frogs are good for fishin'

JB.   they are?

I.   I eat

JB.   do you use those things?

I.   fish I'm I'm a really good meat eater

JB.   you are

I.   I eat [...]'s fish

JB.   really? that's good well thanks a lot Ian.

Data Set #2 – Interview with a biologist about the nature of science

(Interviewer talk in boldface)

And I will give you an articulate erroneous view on things in Hugh's opinion I think.
I doubt it. But its unusual, I think, that most people in science don't read much about science.
No. Well my background is a bit checkered, I mean I'm now in science but I have interest in the arts in architecture and music and uh so I do this because one has to specialize in something to get a job (laughs). If I were independently wealthy I don't think I'd be any more a biologist than I would be a musician, or interested in social history, or any number of other things.
Right
And so from that point of view I guess its a little abnormality. Most, most of my colleagues are quite devoted biologists and as a matter of fact, most of them tend to be rather narrow, they don't seem to see much of interest outside of that.
That's been my experience, that's interesting. Uh speaking I guess on this vein, I've been asking people just how they got into it - how they got interested in science and it might be interesting to see how you got interested in it.
Oh okay sure. Well I guess in the first couple of years in undergraduate work was when my intellectual horizons really blossomed and I was interested in lots of different things and my first year at Toronto I was taking classical languages, zoology, mathematics, psychology, you know a real potpourri of things.
Huh
Um and the thing that kept bringing me back to science was that there was a systematic rationale for both gathering data and for interpreting them uh and it wasn't clear to me that that was the case in say linguistics, or the social sciences or the arts. The criteria, and I now know a little more about criticism and aesthetics than I did then, but at the time, those seemed to be quite chaotic endeavors and whereas science made sense to me and I guess that's why I've been having a strong pragmatic streak, I kept coming back to science, and I would interpret everything else in terms of science - I mean I would engage in psycho-history and scientific analysis of artistic interests and things like that so I guess that is what brought me to things like that.
Huh. So you didn't see any kind of beginnings of this at a younger age?
No. At a younger age, no, I was really very undifferentiated until first or second year undergraduate. I mean prior to that I had taken maths and sciences primarily in my high school training, but I was equally good at languages so I could have gone any number of ways. I mean I'm not good enough to become a professional musician or artist but certainly in terms of the social sciences or intellectual history or anything like that I think I was equally bad at all of those things (laughs).
I don't know about that (laughs). That's quite different actually.
Now since then, I have systematically built quite a uh an elaborate framework you know and things have become quite different in my own activities of course just through job pressures you become much more specialized but that's that's all the more reason.
Yeah that's interesting. You have to or you get lost. Uh I suppose we can just jump right in and uh and go for some of the meaty material here. Uh and it might not be the easiest question to start off with, but in terms of the major theoretical frameworks you see driving your discipline

Oh yeah

What are what are those - those major frameworks?

You mean my discipline do you mean biology? I mean I'm an ethologist I work with animal behavior. Do you mean that subdiscipline? or do you mean biology or a large?

Yeah briefly biology but more extensively...

Okay let me show you a diagram, this may be irrelevant but um I have this is a diagram that a few of us have chuckled over occasionally and this is the way that I see that we organize everything that we do in academics

Uh huh

That if we have if we look at the - we are after beauty, good and truth, okay? It seems to me that one could talk about a theory for the pursuit of each of those, the actual practice and the various applications. And, and so the way I tend to organize things is that for instance within beauty there are aesthetics and criticism in the arts and literature and then there's entertaining and advertising and there's one spectrum for that. And then there's ethics and morals and politics, at least in theory, then there's supposed to be a moral endeavor. Uh and then within science, I see the usual levels of organization from physical science through molecular biology, cellular physiology, ethology, population ecology and community. And that can be done in different species. So I see the social sciences as um a population and community ecology of humans, so all of the social sciences end up in that corner in the way that I look at that whole of the life sciences. And then there's a theory of science including biometrics and the statistical analysis of data and then there are various applications, so I look at engineers and veterinarians and medics as applied

I'd like to get a copy of that

Yeah yeah sure. Yeah you are welcome I can um actually I've got it on the mainframe um but yes I could send you a copy or make a photocopy.

If you are on the mainframe, you could just send me a copy.

Yes. I just don't know what else its stuck in with right now but yes I could do that. But anyway, that's sort of the way I look at things overall. And that means I can read a work by Martin Buber or Northrope Frye or whomever and relate that to what I read about Francis Crick or um um Grachman as a physicist or whoever, it provides a framework.

This is uh a little deviation here but uh I was uh I wrote a paper on Buber teaching science

Oh really

Yeah and the professor that I was taking the course from, it was an Education course, uh didn't like it at all, but he wrote a book on Buber

Uh huh

And uh he thought he was like some kind of authority on Buber. I still think it was a great paper

Uh huh uh huh

But he and I - he finally gave up - it was like we were just missing and he didn't see it the way I was looking at.

When I read Buber its for the poetry in his writing I mean I'm not into Talmodic Studies and and you know and uh all the extra pieces of the tongue and so on and so forth but just for the beauty of his writing.

I was just talking an existential point of view and how it can translate into I forget what I said now

Yeah yeah. Anyway to come back to your question about what moves uh I mean most molecular biologists uh um well I guess there's both the the public objective framework from which the people are working and then there's their own private motivations for doing things. So then you've got um biology is a very disparate enterprise when you think of everything from molecular biology where there are some very well worked out paradigms in terms of Francis and Crick DNA and so forth and there's an enormous amount of what Kuhn would call normal science going on I mean the framework there is now fairly well established I mean there's an awful lot of details to be learned, but the framework for that is established um and in physiology and behavior, well the whole growth in the neurosciences and neuroecology again there are some moving paradigms within which most people work and that's true within population community ecology where fieldworkers, uh uh again there are certain ideas uh stability of ecosystems, competition between species, uh [...] investment patterns uh which uh move people so um biologists, like most scientists, tend to be fairly from a philosophical point of view, pretty practical and hard nosed and fairly naive I mean most of them are not well read. Um and most of them are interested in what works and uh they don't put up with a lot of truck on uh fine philosophical discrimination and so on. In my own area of ethology, the um ethology is traditionally, although ethology has tended to study animals in their natural environments in the wild as opposed to psychology, which tends to work in the lab, they have both been from a philosophical point of view behaviorist or positivistic enterprises. They have looked at the objective behavioral data and seen what they can make of it in very different ways within a Darwinian framework, or a laws of psychology framework. But certainly behaviorist. Whereas the new development of cognitive ethology, I don't know whether you've heard this from Donald Griffin and Carolyn Ristow, to what extent do animals think and so on is a very different approach.

And speaking along this same line
And its primarily stimulated by Genet um with his brainstorms and so forth and Griffin as you perhaps know is an outstanding animal behaviorist he's has done wonderful studies on echolocation, orientation, and migration in animals. I think he's now into his dotage and he's philosophically naivety is showing up in the books and although he's written a couple of controversial and popular books on animal thinking, the people who know anything about either the philosophy or the behavior of the complex behavior in animals um you can see that they are really very shallow books and there is a bandwagon now in cognitive ethology in which there are attempts to apply cognitive paradigms to animal behavior. First of all I think its completely unwarranted and I think its unfortunate from other points of view too because it tends to fuel animal rightists with extra ammunition as to why animals shouldn't be in cages and so forth. Uh I've just finished writing a book on animal motivation and uh I had a section in there this is on cognitive approaches on ethology of motivation because from the point of view of a moving paradigm that's certainly one corner of the field where there's been a lot of noise well a lot of smoke generated but I think very little light.

Uh huh
And I think it will pass because I think uh the exponents of cognitive ethology refuse to state what data would discriminate between their position and a position where you would interpret behavior in terms of well acknowledged mechanisms like natural selection or operant conditioning or something like that and I think that scientists still agree with James that its got to make a difference to be a difference. That was James, or was that Watson? Anyway whichever it was of those and they just simply will not specify and I've gotten into a lot of heated arguments

and they will not specify what data would differentiate their position I mean we've had lots of [...] discussions about well we're interested in animal intentions and beliefs and so forth but uh until they say

Well that's much way off the

Oh yeah its way out. It's way out I mean everybody acknowledges that animals must have um some sort of cognitive rules which are implemented through some sort of neurological mechanisms, which enable them to deal with the situations that they have to interpret whether its flying, courtship behavior, finding food, avoiding, I mean nobody argues about that but all of that work is done within a well identified regular that's normal science. But these people are really right out. So that's kind of different. Now I don't know if that really deals with your question, but that's sort of an overall for all of biology and a specific within my own substance.

Yeah that's more than I - much better than I've gotten so far.

Yeah alright (laughs).

So I guess then the next question following up on this is how you specifically relate to the theoretical framework that you are working in. How does that affect your research?

Oh very much. It motivates me very strongly um my own, I'm talking now as being trained as an ethologist in the tradition of Konrad Lorenz and Niko Tinbergen and certainly that framework while its not purely a dated framework um and oversimplified as most frameworks tend to be you know most frameworks turn out to be special cases of more complicated situations, none the less they put up the major girders of the structure to which the rest of us can usefully add.

Uh huh

And I should point out that that is not a popular framework, that is a European framework and in the Anglo American world, Lorenz and Tinbergen are not well acknowledged as leaders in the field, especially Lorenz because of his political associations with the Nazis in the second world war and so forth. But none the less the way they look at things provides me with a very strong framework because it pulls together uh biology always has questions about mechanisms and questions about function uh and what Lorenz in particular was the first person to do um very much in the Darwinian tradition and Darwin was less concerned about some of these details um but what Lorenz did was to put together what we knew about approximate mechanisms of behavior in terms of animals having drive systems to do various things. We have a functional account of how this was adapted for the animals to do so. Um and I personally think that in the Anglo American world his contributions were not acknowledged for what they should be and I think I make that case in there. Yes I certainly have a strong driving paradigm in my own work um and I recognize it because I see it absent in so many of my colleagues and students. Um and occasionally I see other paradigms in other people I mean I know some people for instance there are a few people here that are reading [...] volumes they look at everything from functional point of view. They don't care about mechanisms at all so they have quite a different, I think flawed, but quite a different paradigm so certainly there are different [...] work with different paradigms. Certainly my own paradigm I've found to be very fruitful as a coordinating and driving mechanism for my work.

Right. So how do you see yourself relating to the evolutionary framework?

The evolutionary framework? Well what I see in my own research which mechanisms provide the mechanisms that generate the behavior which adapts the animals to its niches. And whereas behavior ecologists are more interested in how animals actually survive and reproduce in an environment, so they are more interested in the functional aspect of it whereas I'm more interested in the details of how that behavior is produced.

Right

And then on the other side of that of course is that I have some friends in physiology who are actually looking at the wiring and the hormones and the real hard nitty gritty stuff the engineering aspect, I mean its the difference between um black box using a computer and actually looking inside and looking at the transistors and stuff.

It seems like a lot of, at least in the States, uh well with my background in animal behavior which was early seventies, it was much more I'd say well we did look at Lorenz and diversions and a lot of the mechanisms but then I noticed in Houston a few years ago the animal behavior courses were almost all physiological.

Mm hm. Well I think there is yes there are two major peaks now there is the tremendous development of the neurosciences and the study of neural and hormonal mechanisms at a very complex level and vast array of neural transmitters and complexity of the wiring diagrams, and the neural sciences is a huge huge growth. And the other big growth is functional aspects, socio biology, field studies, encouraging extension of the human behavior.

Right right. Um I guess we could play around with the topic of evolution, what you see as the um, or how you see evolution in terms of how you see evolution being taught in terms of elementary or high school. I guess elementary school would be more on topic.

(INTERUPTION - TELEPHONE RINGS)

(Answers telephone)

I'm sorry, evolution and being taught. I have no pedagogical training. The only person in our department who has formal pedagogical training is Henry Hood, our Undergraduate Chair, and who is also very interested in history and philosophy of biology so he's somebody who if you haven't already thought of

He was one of my, my initial, my first one

Oh oh sure. So I'm speaking rather naively because I don't know very much about pedagogy in the formal sense. Um I would think that um evolution should be taught as a fact. It is a fact in the sense that if there is an overproduction of - if we just take Darwin's paradigm: overproduction of offspring, heritable variation on traits on which there is selective pressure, and um restraints in the environment such that uh not everybody is going to live to reproduce. Given that system then selection automatically occurs. It's a syllogism. Uh and I think that would be the way to approach it as just the fact that this is the way. And then of course, there are lots of examples and details that one could go on from there. But I would present it as a natural outgrowth of our observations on natural history and I would certainly keep it away from creationist theories and so forth as far as possible. It has no more to do with uh theological questions than anything else within science does. I should say no much more or less than anything else.

Right right. Okay then, I guess specifically, if you had your way uh how would you like to see science taught, including evolution and anything else about science in the elementary school?

Okay. Well first of all, science has been traditionally poorly taught especially in the elementary because very few of the teachers have training in science I mean I know that from our own kids in school and occasions when parents, scientifically orientated parents of kids have said look I'll be happy to give you a lab, or I took Andrew's class a few years ago to the Alice Hall observatory just so they could learn a little bit about astronomy and so forth so one thing they need first to have a teacher who provides who has the appropriate training and attitudes toward science, it seems to me that is important and also to make sure there is time in the curriculum for hands on experiments. Now I know they have to be carefully designed and there are limitations

of budgets and so forth, but actually have some hands on experiments um it concerns me that um, I get the impression sometimes in schools that there is a lot of emphasis on English and perhaps Arithmetic and um Phys.Ed and History, and Art, I'm also concerned about the low role that Art and Music have in the curriculum, I know the day is only so long but um but Science often consists of simply some bus trips out to the conservation area and walking around. And that's certainly lovely but of course the kids don't pay much attention to that I mean they're outside and they run around and play tag and having a good time, so I guess I would like to see some more systematic experiments in terms of what we're doing. I think the curriculum's not too bad at least my impression of it from what I've read through Andrew and Jeffrey's notebooks and they show me the experiments they've done and of course their science fairs are very good and uh that really encourages them to get into projects and that.

How old are your kids?

They are fifteen and a half almost sixteen, and one thirteen. So one is in KCVI and the younger one is in Winston Churchill in grade 8 although he enrolled in English and Math in grade 9.

Uh huh

Winston Churchill is of course, well I suppose that the parents in the neighbourhood tend to be academics is a very academically aware school and I'm sure that in general things tend to be not so good (interruption- telephone rings) and that's bad because science is so important in our society. In many other schools, science I suppose gets even less emphasis and it bothers me in the same way that it bothers me that Parliament is filled primarily with lawyers instead of scientists and engineers. I'm just bothered by all the ignorance that we must [...] especially if we believe in having a democratic society which is going to vote on issues of which scientific knowledge is important.

Right

But that's a general concern amongst science professors in particular, I'm sure.

Yeah I hope so. I don't know that people think about it much. You mentioned one thing in here that it is important for students to study science in the elementary school, uh, on the questionnaire, you said, "yes, science is the chief engine of our cultures, as well, activity of great study value". Both of those things - engine, intrigues me, what you see that as being as well as the great aesthetic value.

Why its an aesthetic value? Sure. Well on the engine, our society runs on science and technology and you know whether you like that or not and whether you want to do an Allan[...] or whether you want to demise a medieval theological framework, or whether you want to resurrect an Islamic theocratic state or whatever, our society runs on science and technology and we use that tiger and the tiger is there and having started out on that track, and while it is clear that we have to make ethical choices as for instance as to medicine and what we are going to do about it, nonetheless those developments can be made, they will be made, we have to know about them in order to handle them properly. So that's the engine part of the comment. The aesthetic value is that I find doing science, both its quantitative aspects, the modeling and theoretical aspects, and the joy of investigating the natural world. Just watching it, "Hey! Look at this," as rewarding. For instance, I seem oratorial, and tonight, for instance, we are doing the Verdi Requiem and the almost excruciating beauty of that piece to sing. Its the same sort of thing. Its just an enormously pleasurable aesthetic experience.

Uh huh

Now mind you in science much of it is associated with a great deal of sweat and hard work and dog work and all that sort of thing, but the thing that drives it all certainly is the aesthetic enjoyment.

Yeah it seems that uh taking that point of view in elementary school is something that is often missed. I mean, teachers don't see science as being aesthetic.

No no most of them are probably trained in the humanities and don't know about it and even if you did know about it its difficult to get it across. That's the whole problem with pedagogy to enthusiastically and lucidly transmit the both information and attitudes, its not easy and its something most of us struggle with before our well motivated audiences here at Queen's.

Right. Uh from this survey that I did with my BEd students last year, something in the order of 50 per cent of them had not taken any natural sciences at the University level.

I find that appalling

Yeah its just shocking. Between 75 and 80 per cent had taken one (both speaking at once)

In the same way that I see Biology students here taking 5 biology courses and they are taking no languages, no music nothing of, I mean there's something to be said for enforced breadth.

I went to a liberal arts uh college in the States and we had to take everything

Yeah take some of everything yeah there's something to be said for that sure.

I guess um the other point on here one the rating scale you rated your labs and lectures you moderately disagreed with the statement that they were the most important part of science, yet you you know you were talking about problem solving designing experiments you teach that those and that you strongly believe those

Yes yes

And uh strongly agreed with all theories, concepts, fact and methods of science being in an elementary schools. I'm just

Yes well why the lectures - well the reason I was scoring like that is that they are certainly necessary but not sufficient. Um it even bothers me with the labs here some of the students are running around doing labs for three hours on something- they study photosynthesis of they cut up a fetal pig or something uh and what's the concern to the people running those courses and the rest of the people is whether the students are learning learning some general principles and concepts beyond, oh well we've got to know these muscles for the midterm exam in three weeks time and I guess my hesitancy on that is - refers to the fact that certainly that sort of experience is necessary but that's not what all of science is about.

Well how do you see, or how do you describe the ideal science course?

Okay certainly hands on - well lectures to provide an overview of the information, and practical experience either in the lab or on field trips is good but I think what is really important is for the especially for the professor and the instructors and demonstrators is to emphasize the concepts and general purpose and objectives of the course so that the students don't get lost in the woods and don't see the forest and that they are still excited or so busy learning all of the bones in a comparative anatomy course that they don't see how all of that functions together to make the animal what the animal that it is and that sort of thing so I guess I feel that we have so many students who are so orientated toward specific bits of information - do we have to know that for the final? You know that perennial question and to make sure that the more general objectives in terms of disciplined thought and the excitement of all of this and the beauty of the principles that arise out of it are not lost in all the busy work.

Right

That's my feeling

Right that's interesting. The other I guess, before we leave teaching, there's one more on the subject- you mentioned teachers having the right kind of background especially in elementary school. What would you see as teachers having the appropriate training for elementary schools?

Well it would be nice if well elementary teachers they tend to they have to cover the whole gamut with their class at the elementary level and I would think that that would mean that and I think that's different from intermediate or upper level teacher who teaches language or languages or history or science or whatever. That means that really that those people themselves should have a fairly broad training that they would want to have a liberal in a literal sense, some science, some language some history whereas if you look at all levels of education both the students and the instructors all become very specialized and if you look at graduate education, the students are really specialized and their instructors are really specialized and I think that at that level you would want to make sure you really had generalists but I would suspect that most of them are arts and history graduates and so forth.

But specifically in terms of science what would you like?

Well one thing yet, um I think every science department at Queen's runs a solid course in the sense of having good material in it but its for non majors and I think that's true.

[SIDE TWO]

Elementary teachers should have at least three courses from the areas of physics, chemistry, biology and geology something like that, because if they had at least three of those areas I think that would give them enough of a background to get on with because we're not asking about a terribly high level but they've got to know enough of the overall principles that they can do a decent job with the kids.

Right yeah. That's what we're trying to do I mean um there are battles going on to get some kind of a background.

Again as I say, I am very naive on these matters and I don't know much about pedagogy itself because I am a practising scientist not a teacher.

You're not expected to. Its just nice to get the view of the professionals in the area.

Uh huh yes

What they'd like to see in the profession and there's quite a bit of variation between what I've seen so far between departments.

Uh huh, really

A little early to tell just yet

Can I just add a comment?

Sure

It seems to me that if the shoe were on the other foot, I mean people who were in the arts or music or whatever, consider other individuals to be bores if they don't know anything about art and music and yet it is not considered to be borish to know nothing about science and in fact it is, I mean it is just simply uncivilized to know nothing about science. I mean the two cultures really is still a valid metaphor.

Yeah it's a shame I see very little difference certainly between art and science.

As intellectual enterprises, I think I find that I can move easily between the two

Oh yeah

Um but unfortunately there are- I mean most music students, I sing in the Queen's Choral Ensemble, and most of the music students there are taking no science and that's as bad as biologists who are taking no art.

Right. That was a big conflict with me, you know I was in biology since I was about twelve years old.
Uh huh. Oh a long way back then
Yeah
Much more committed than me (laughs)
And I sort of questioned it in College where arts and philosophy and a number of other things just started to intrigue me
Uh huh
And I almost switched, but I stuck to it. Interest.
Uh huh, hm
The last thing that I have to talk about here is a kind of a simple scenario - again its interesting to hear what people in other departments are saying about it but uh, if you were to consider two situations, I guess which situation would you see as being problematic, or what are the problems involved in each situation: An oil tanker spills its contents along a coastal area
Chemical [...]
Right, and the other situation would be a developer putting up another extensive housing development in a marsh land.
Collins Bay (laughs) yeah
Yeah. What do you see as the problems involved in each situation which would you consider would may be the worst?
Well um, I guess a lot of the ships with cleaning out their bilges and so forth and polluting um that's a problem that as many people find out of a multinational scale, of the traditional national laws that apply to what happens in national boundaries, there just isn't the control over multinationals that we need, in the same way that we regulate fare- or at least that we can regulate what goes on within better defined areas. Um and we really are a global village now, and being a world federalist until we get some sort of government which can effect the same sort of control over let's say oil spills or those sorts of things which happen outside of normal areas of jurisdiction that we need to develop mechanisms that are just as much within the traditional narrower scope of things. Um and obviously just of the magnitude of those sorts of accidents and the devastation and the difficulty of dealing with them, they can be tremendous, I mean the [...] and other sorts of accidents, I mean they can be really horrendous um not nearly as horrendous as nuclear, I think that nuclear threats are much worse because oil is terrible but oil is at least an organic compound
Right
As nuclear materials um I think we have really got a tiger by the tail there and I that's one that we have really ought to back off I'm afraid. I'm very anti nuclear, uh that's just a personal viewpoint. Um the developers around say the Collins Bay sort of thing, there again one needs to have an informed and alert populace and who will make sure that their government maintains the appropriate regulatory watchdog role um and not just let things pop up because somebody adroitly grabs some land and puts a whole lot of buildings on it. And um I suppose on a scale, well I suppose that in terms of the total number of dollars involved, something like a major oil spill is probably a bigger mess on the other hand it may affect fewer people directly if they happen to be along the coast of Brittany there won't be too many affected by that whereas um many developments occur in areas where a lot of people, the quality of life of a lot of people is affected, as the discussions in Toronto in what's happening as to the access to the shoreline there

and because of the developments along there and how that's decreased the quality of life of everybody in the city who enjoyed that shoreline. So its hard to say which is a worse situation because in both cases we need to ensure that we have an alert populace to ensure the existence and implementation of the appropriate regulatory mechanism so that we can develop our resources in a way that is satisfactory.

Yeah um so the major problem is in terms of development is how it affects people, in both cases it affects the populace. It's interesting.

Uh huh mm hm. That's it.

That's good.

I would urge you also to speak to David Dennis our department head, and also Dalt[...] who has been interviewed by the CBC on the teaching revolution of the public schools. They are both informed and bright people whose views I think you would find interesting, I think along with Henry Hood.
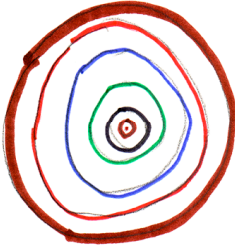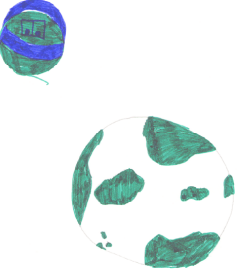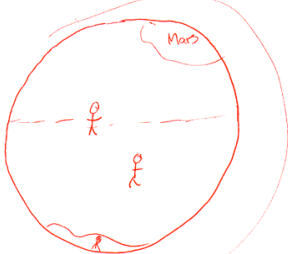
Dalt has indicated his interest in his questionnaire.
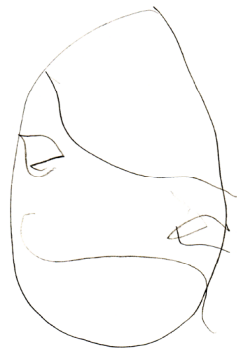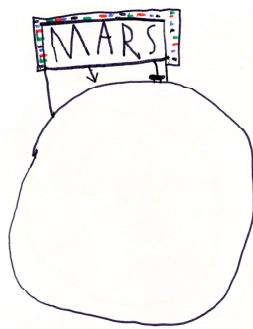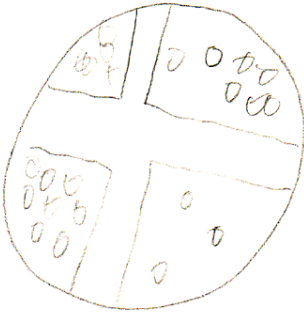
Yeah he's away in Holland right now for a couple of weeks and he'd be back soon and I would say David Dennis too I think.

He didn't respond. I spoke to him but I don't think he filled out a questionnaire.
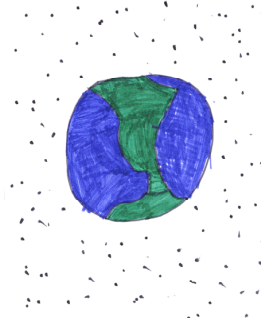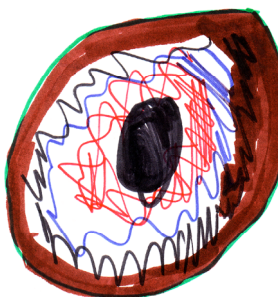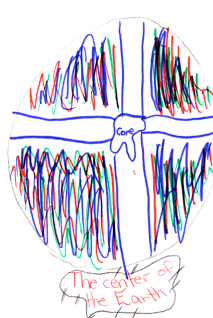
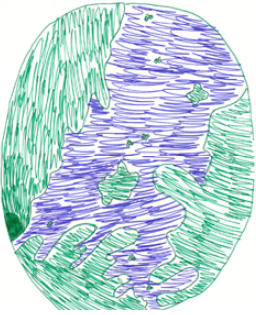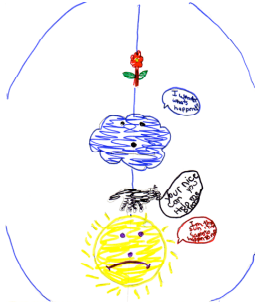**Data Set #3 --** Grade 5 Children's Drawings and Comments About Earth

Draw a picture of Earth as seen from outer space.	Draw a picture of Earth after it has been cut in half so that it shows what is inside.	Draw a picture of an eclipse on Earth as seen from outer space.
Allison Okay, this is Canada here... this is Alaska, this is the US here, this is South America with Brazil and Chile and all that. This is Mexico, this is Africa, this is Europe, this is the start of the Soviet Union. Greenland.	 I don't know how to do layers. I guess that 's the rock, I just didn't know ... the earth. I mean the lava rock or hot rock or whatever that is.. I don't know what the yellow one [2nd from center] is. And, um .. just I guess different colors of soil, maybe or ..	No picture drawn.
Rani (girl) 	 That 's sort of the outside part of the earth if you cut it… You'd have people all over. [Screaming help] Yeah. Only those would be my parents, and little animals [falling into the cracks]	No picture drawn.
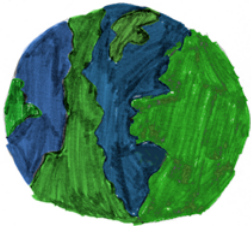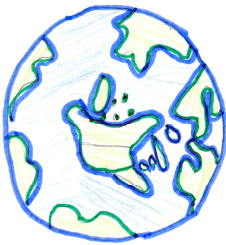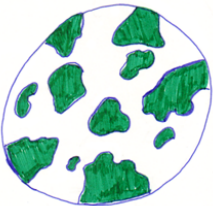
Earth from Space	Earth cut in Half	Eclipse as Seen from Space
Barbara		
Charlie		
Ellie	Inside I think that there would be more people. 'Cause I think that if the earth's so big it's all around it... and some people can't go upside down so the bottom's sort of like a floor inside. If you cut it in half then there'd be like... more people inside like. I think that there can't be like they're all around here. I think that there are probably some people down and some people up here. I think there's some water all around here and I think that inside the earth there's some people. Persons here and there's some people up here and there's different planets around and there's... different planets here where there's people… up here say there's Mars and there's like some people there and there's down here different people… red people.	No picture drawn.

Earth from Space	Earth cut in Half	Eclipse as Seen from Space
George		
Heidi		
Jack		
Jesse		

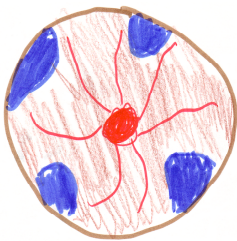| Earth from Space	Earth cut in Half	Eclipse as Seen from Space
Jake		
Keith		
Kelly	 It has a core... rock. [The cross is] ... holes. [Can we dig holes like that?] No, not really.	No picture drawn.
Lynne	No picture drawn. Mostly, rocks, soil and lava and stuff like that [inside the Earth].	No picture drawn.

Earth from Space	Earth cut in Half	Eclipse as Seen from Space
Mark	No picture drawn.	
Madeline		
Marilyn		
Melinda		

Earth from Space	Earth cut in Half	Eclipse as Seen from Space
Nelson	Rocks, dirt, fire, molten rocks, worms [inside the Earth]. [Later he also referred to "roots."]	
Phong	No picture drawn.	No picture drawn.
Jayashree		
Tim		
Talia		No picture drawn.

PART IV
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