Figurative Structures of Thought in Science

An Evolutionary Cognitive Perspective on Science Learning

Talk presented to the General Assembly of the Conférence des directeurs de gymnase de Suisse Remande et du Tessin, Mendrisio, September 18, 2009

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Overview and Goals

1. **Introduction**
2. **Origins of imagination**
3. **Structure of imaginative thought in science**
4. **Using imagination in science**
5. **Beyond formalizing mythic thought**

My goals for this talk are…

- to demonstrate that simple, everyday imaginative (figurative) conceptualizations of the world around us are used as the foundation of conceptualizations in science…
- to argue that we can make use of these figurative structures for science pedagogy from kindergarten through high school (by, among other things, integrating language and science)…
- and to mention that a physics curriculum that makes use of these structures already exists in high school (in the Ticino).

1 Introduction

Alex's story (E. Sassi)

On a winter day, when he was five years old, Alex came home from kindergarten. He talked to his grandmother about how the teacher had told them they should close the door or cold would come in. His grandmother wanted to know from Alex what cold was. He said that cold was a snowman. A snowman was very cold and if he hugged Alex, the boy would get cold too and could get sick. Alex and his grandmother were outside and decided to build a snowman. When his grandmother wanted to build a big one, Alex said that a big snowman would be so cold it could even kill young Alex. Alex thought it would be better to build a small snowman.

Now his grandmother wanted to know what he thought heat was. Alex said, heat was a man of fire, or maybe a dragon. Alex could play with little dragons, they were not so hot and dangerous, but a really big dragon would be so hot and strong, its fire could kill the boy.

Questions

1. What is the origin of the structures of imagination revealed in Alex's story? How does this relate to the evolution of the human mind and the development of the mind of a (young) individual?
2. What is the structure of this imagination? How can research into figurative language help us identify this structure?
3. How can these structures of thought be used to develop a modern science curriculum? To what extent can it be called the foundation of conceptualization in science?
4. Does the structure revealed here go far enough in providing the basis of 20th century physics and chemistry, or do we now use other, more modern (figurative) structures in current science?

2 Origins of Imagination

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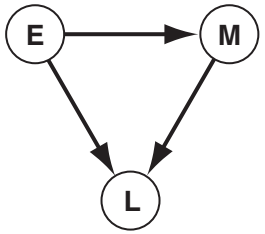
Evolution of the Human Mind

Donald[a]	Egan[b]	Language	External Media and Tools	Age
Episodic	Somatic	Reaction to events		6 Ma
Mimetic		Body language		2 Ma
Mythic	**Mythic**	**Spoken language**		100 ka
Theoretic	Romantic	Written language	Stone, Paper	10 ka
	Philosophic, "modern" realism	Written language, Formal languages	Paper, Film, Computer, RAM, HD, DVD, Experiment	1 ka 100 a

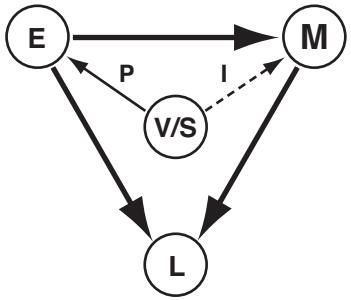
a. Merlin Donald (1991): *Origins of the Modern Mind. Three Stages in the Development of Culture and Cognition*. Harvard University Press, Cambridge.

b. Kieran Egan (1997): *The Educated Mind. How Cognitive Tools Shape Our Understanding*. The University of Chicago Press, Chicago.

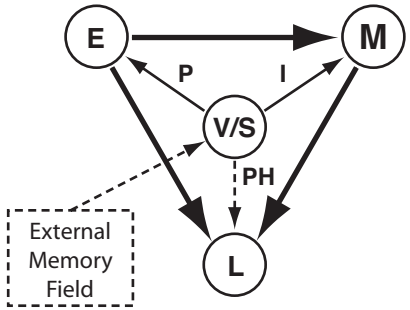


V/S Visuosymbolic system
P Pictorial path
I Ideographic path
PH Phonological path

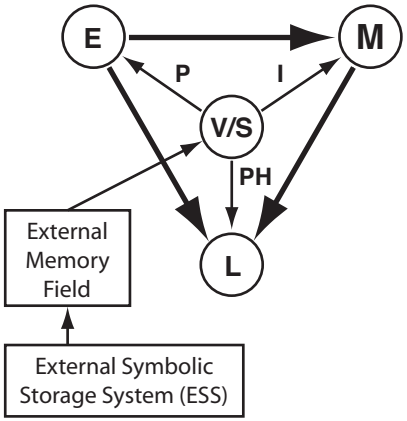
Level III Archaic Human



Level IVa
Pictorial V/S path (P)
Late Paleolithic



Level IVb
Ideographic-analog V/S path (I)
Hieroglyphs, Chinese: Bronce Age



Level IVc
Phonological V/S path (PH)
Alphabet: 1st Mill. BC

Development of mimesis, spoken language, and literacy as forms of representation (modeling) of an older form of understanding with the help of new tools. According to Donald (1991, p. 305).

Merlin Donald: Mimetic Culture

EPISODIC CULTURE	(Donald, 1991, p. 198)
+ MIMETIC SKILL	• intentional representations • generative, recursive capacity for mime • voluntary, public communicative system • differentiation of reference • unlimited modeling of episodic events • voluntary auto-cued rehearsal
+ SOCIAL CONSEQUENCES	• shared modeling of social customs and hierarchies • reciprocal mimetic games • enhanced conformity and coordination • group mimetic acts • slow-paced innovative capacity • simple pedagogy and social attribution
= MIMETIC CULTURE	• toolmaking, eventual fire use • coordinated seasonal hunting • rapid adaptation to climate, ecology • intricate social structure • primitive ritual (group mimetic acts)

Merlin Donald: Mythic Culture

[…] mythical thought, in our terms, might be regarded as a unified, collectively held system of explanatory and regulatory **metaphors**. The mind has expanded its reach beyond the episodic perception of events, beyond the mimetic reconstruction of episodes, to a **comprehensive modeling** of the entire human universe. **Causal explanation**, prediction, control—myth constitutes an attempt at all three, and every aspect of life is permeated by myth. (Donald, 1991, p. 214)

[I shall attempt to show that mythic structures underlie much of our useful every-day as well as scientific thinking…]

Cognitive Tools: Development of a Young Human

Kieran Egan: Mythic Understanding

[Mythic understanding…] is a product of learning to use an **oral language**. […] Universally, in all human cultures, the development of oral language involves a set of cognitive tools, such as the use of **stories** to give shape and affective meaning to events, the use of **binary oppositions** to provide an initial grasp on phenomena, an engagement with **fantasy**, […] So I will consider what stories are and why they engage children so powerfully, why children are so attracted to fantasy, why they enjoy **rhythmic language**, why forming their own **images from words** is so important, why emotionally charged binary oppositions are so prominent in their **imaginative lives** (security/anxiety, courage/cowardice, love/hate, etc.)… (K. Egan, 2001)

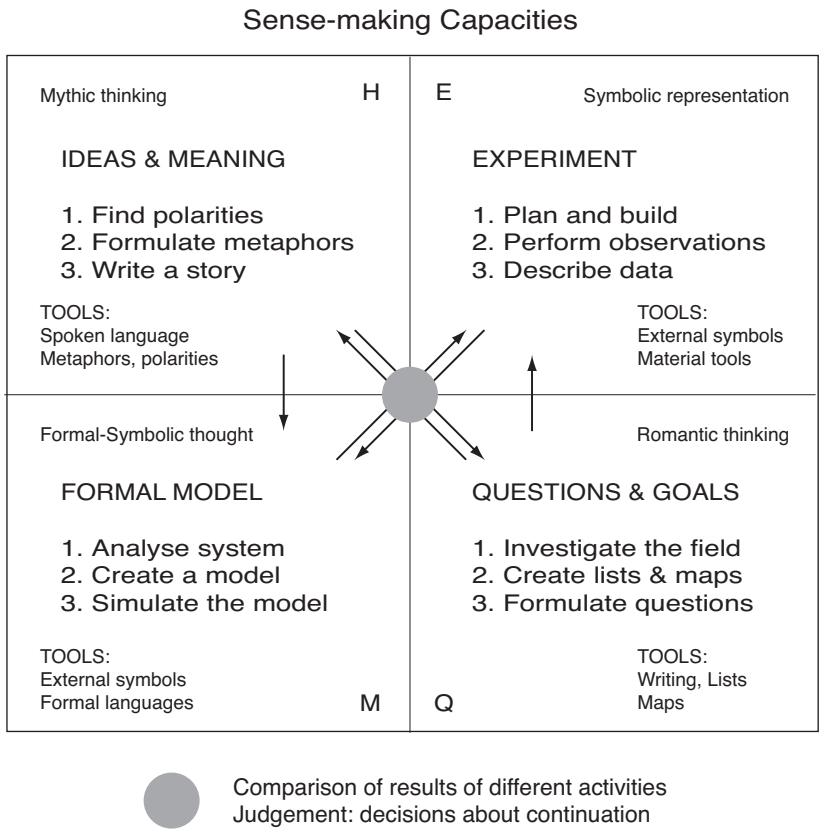
Binary oppositions: **Polarities**.

Kieran Egan: Mythic, Romantic, and Philosophic Understanding

Cognitive tools (K. Egan, 2005)

Mythic Thinking	Romantic Thinking	Philosophic Thinking
Story	The sense of reality	The sense of abstract reality
Metaphor	Extremes of experience and limits of reality	The sense of agency (causality)
Binary opposites (polarities)	Association with heroes	Grasp of general ideas and their anomalies
Rhyme, rhythm, and patterns	The sense of wonder	Search for authority and truth
Jokes and humor	Collections and hobbies	Meta-narrative understanding
Mental imagery	Knowledge and human meaning	
Gossip	Narrative understanding	
Play	Capacities for revolt and idealism	
Mystery	Changing the topic and the view-point	
	The literate eye (forms, lists, flow-charts, diagrams, maps…)	

FUCHS: THE FOUR-CYCLE



The Four-Cycle (Fuchs, 2007) as an integrated model of scientific practice and thought. It adds Egan's (1988, 1990, 2005) elaboration of mythic and romantic sense-making capacities to a double-cycle representation of scientific methods and technical design.

3 Structure of Imaginative Thought in Science

Questions

1. What is the origin of the structures of imagination revealed in Alex's story? How does this relate to the evolution of the human mind and the development of the mind of a (young) individual?
2. **What is the structure of this imagination? How can research into figurative language help us identify this structure?**
3. How can these structures of thought be used to develop a modern science curriculum? To what extent can it be called the foundation of conceptualization in science?
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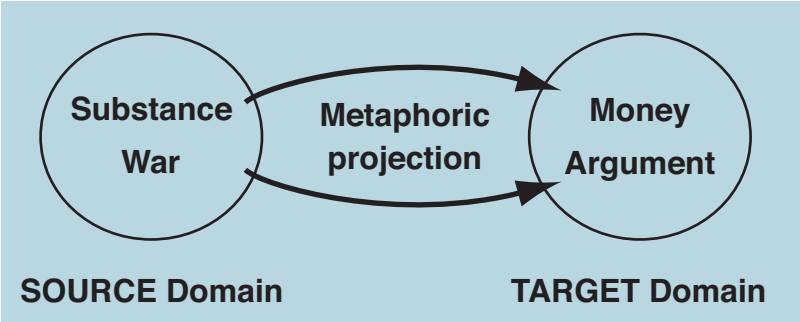
Examples of Conceptual Metaphor

Class	Metaphor	Linguistic metaphoric expression
Orientational	more is up	The number of books printed each year keeps going up
	similarity is closeness	These colors aren't quite the same, but they're close
	states are locations	I'm close to being ill, and a little more will send me over the edge
Ontological	purposes are desired objects	I saw an opportunity for success and grabbed it
	categories are containers	Are tomatoes in the fruit or vegetable category?
	money is a substance	Put money into your account!
Structural	life is a journey	Two roads diverged in a wood, and I — I took the one less travelled by, and that has made all the difference (R. Frost)
	argument is a journey	We've covered a lot of ground
	argument is war	I defended my argument
	ideas are food	I cannot digest all these facts



A metaphor projects understanding or knowledge of a source domain onto a target domain.

A comparison of traditional and CL views on metaphor (Kövecses, 2002)

Traditional View	Conceptual Metaphor Theory
Metaphor is a property of words, a linguistic phenomenon	Metaphor is a property of **concepts**
Metaphor is used for artistic or rhetorical purpose	The function of metaphor is to better **understand** certain concepts
Metaphor is based on a similarity between two entities that are compared	Metaphor is often NOT based on similarity; it **creates similarity**
Metaphor is a conscious and deliberate use of words; you need a special talent for metaphor	Metaphor is largely **unconscious**; it is used effortlessly in everyday life by ordinary people
Metaphor is a figure of speech that we can do without; we us it for special effects; it is not a part of human thought and reasoning	Metaphor is an inevitable process of human **thought** and **reasoning**

Image Schemas

Examples of Image Schemas: M. Johnson (1987); W. Croft and D. A. Cruse (2004, Chapter 8); O. Jäckel (2003), Fuchs (2004b).

Polarity	light-dark, warm-cold, female-male, good-bad, just-unjust, slow-fast
Space	**up-down**, front-back, left-right, near-far, center-periphery, contact, path, scale
Process	process, state, cycle
Container	containment, in-out, surface, full-empty, content
Force / Causation	balance, counterforce, compulsion, restraint, enablement, blockage, diversion, attraction, **manipulation**
Unity / Multiplicity	merging, collecting, splitting, iteration, part-whole, mass-count, link
Identity	matching, superimposition
Existence	removal, bounded space, object, (fluid) **substance**

Rich Experiential Gestalts and Force Dynamic Gestalts

Figurative structures in justice

Quantity	I don't think there is much justice in the world Justice denied anywhere diminishes justice everywhere
Quality, Intensity, Level of	The quality of justice in capital cases The growing intensity of justice, freedom and security The level of justice was not significantly associated with...
Force or power (Agent)	The Healing Power of Justice Accept, my Friend, what Justice makes me do…
Balance	The gross imbalance of justice displayed by these people
Polarity	How to distinguish justice from injustice in our characters
Tension	This tension of justice and mercy also can be analyzed in economic terms
Figure-Ground Reversal	a. With this move we are coming closer to true justice. b. He got the justice he deserved.

Egyptian Cosmology

- **Creating and maintaining polarities (tensions)…**

In Egyptian mythology, Shu (air) separates Nut (heavens) from Geb (earth). The sky must be supported lest it falls down to earth. http://www.civilization.ca/civil/egypt/images/reli28b.jpg

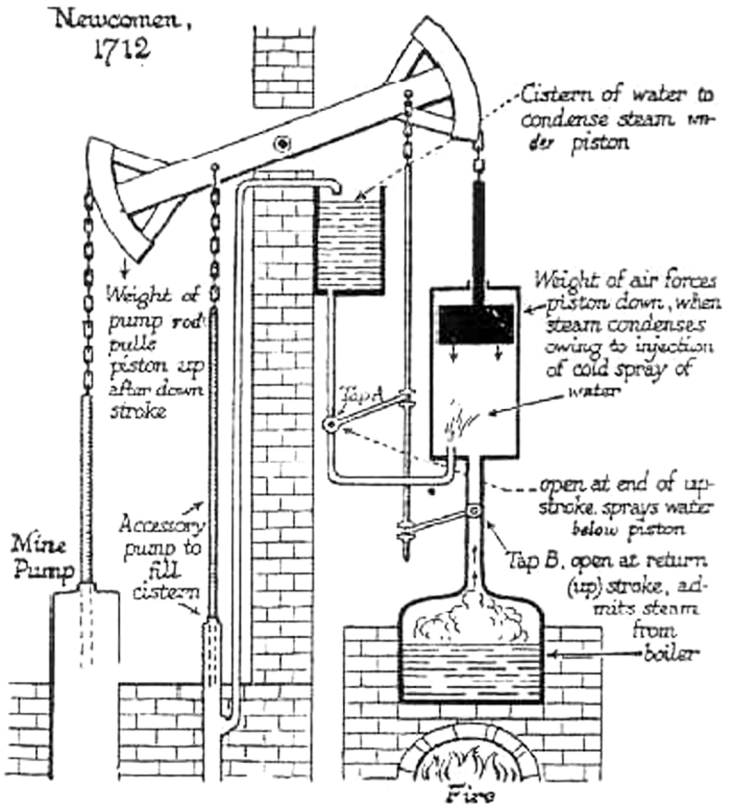
The dynamics of the world enfolds between the poles of polarities. Substances (such as maat) flow and create dynamics.

The Structure of Carnot's Thermodynamics

Sadi Carnot (1796-1832)

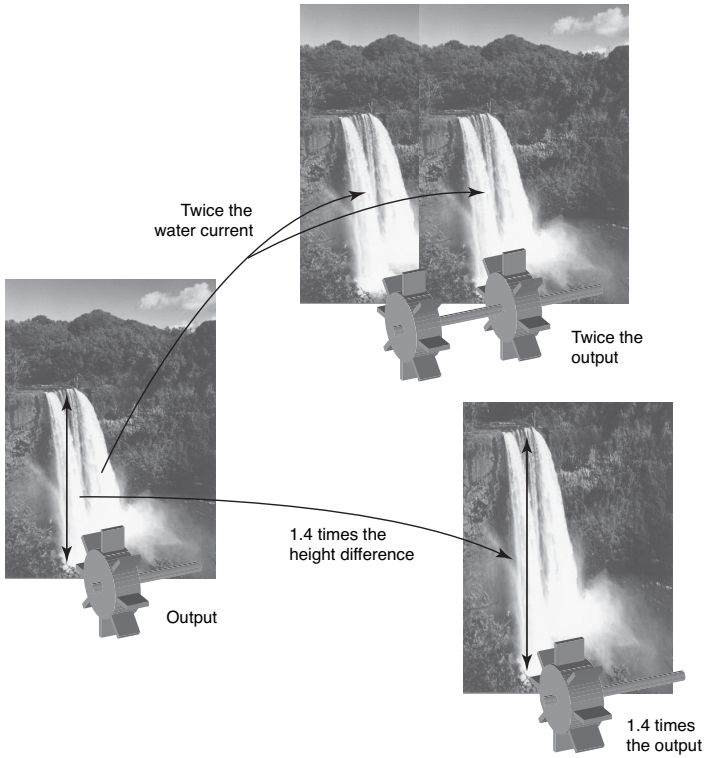
Réflexions sur la puissance motrice du feu

D'après les notions établies jusqu'à présent, on peut comparer avec assez de justesse la *puissance motrice de la chaleur* à celle d'une chute d'eau […]. La puissance motrice d'une chute d'eau dépend de sa hauteur et de la quantité du liquide; la puissance motrice de la chaleur dépend aussi de la quantité de calorique employé, et de ce qu'on pourrait nommer, de ce que nous appellerons en effet *la hauteur de sa chute*, c'est-à-dire de *la différence de température* des corps entre lesquels se fait l'échange du calorique.



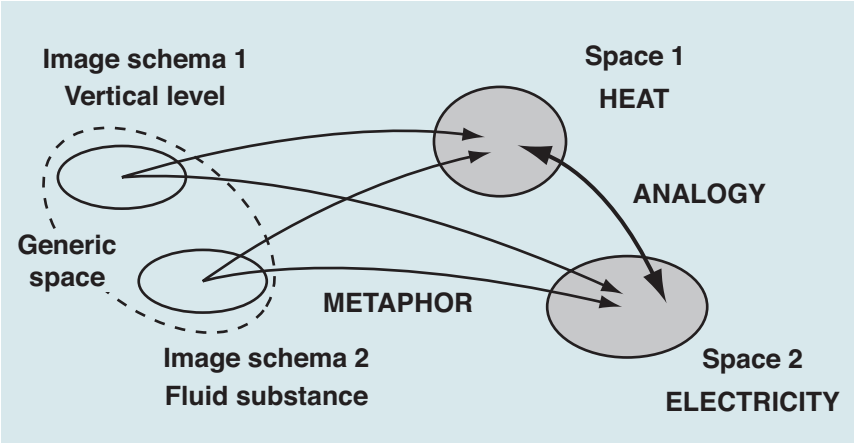
DIAGRAMMATIC VIEW OF NEWCOMEN'S ATMOSPHERIC OR FIRE ENGINE (1712)

THE POWER OF A WATERFALL



Power of a waterfall. The power is proportional to the flow of water and to the height through which the water falls. This image can be transferred to all physical processes.

Image Schemas, Metaphor, and Analogy



Two phenomena such as heat and electricity acquire similar structure due to our projection of the same schemas upon each domain or space. This allows us to map elements and structure between the spaces of the phenomena. Note that, in general, the mapping is bi-directional. We can understand thermal phenomena in terms of electric ones, and vice-versa.

4 Using Imagination in Science

Questions

1. What is the origin of the structures of imagination revealed in Alex's story? How does this relate to the evolution of the human mind and the development of the mind of a (young) individual?
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DEVELOPING IMAGINATION…

- Alex' story of snowmen and dragons tells us where to start. We should let young children, from kindergarten on, develop their **capacity of storytelling** and encourage them to make increasing and conscious use of the elements of FDGs. As a child gets older, maybe already before the onset of the romantic phase, we can slowly help him or her to become aware of the **difference** between **quantity and quality**, or **intensity and power**. Without this, a deeper understanding of natural and other phenomena will not become possible.

- The years following the mythic phase of early childhood deserve just as much attention. We have to develop a science pedagogy for **middle school** (secondary school) that applies the **cognitive tools of literacy**—distinct from those of formal philosophic or theoretic thought—to physics and the other sciences. The distinction of aspects of undifferentiated gestalts which should be achieved during earlier years must be strengthened and followed by a phase where information gathering and organization increases students' **detailed knowledge of physical reality**—without leading to formally structured theories of phenomena.

- Mythic structures of imagination are indeed the **roots of our understanding** of (much of) nature as a look at quantum and statistical physics shows:

5 Beyond Formalizing Mythic Thought

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- Our current view of nature seems to require us to see the world as a vast **mechanism** in which the **motion of little particles** causes all phenomena. This is particularly evident in thermal physics where heat is commonly understood as the result of the random motion of countless little particles. [Actually, if we want to make use of the kinetic theory of gases to introduce a relation between the energy of random motion of particles and temperature, we need to already know what temperature is. There is simply no way around **grounding** our knowledge of nature **in our embodied imaginative understanding** of which the aspects of the FDGs are the main constituents.]
- Do modern quantum physics and statistical mechanics add **fundamentally new concepts** that go beyond a mere formalization of the mythic basis of scientific thought? It seems to me that there may be two concepts that are commonly associated with modern philosophic or theoretic thought, namely, **particles** and **chance** or randomness.
- At least in the form in which it was created by the Greek atomists, the doctrine of particles has much to do with the modern concept of **individuality** or **self**. The discovery of the self is typically associated with post-mythic literate culture and is an element of the desire for **ultimate (absolute) or transcendental reality**. The atom as the final indivisible building block of matter fits this desire.
- As to randomness, I do not know much about its origins and its cognitive status. It remains to be seen what the fundamental conceptualizations of 20th century physics actually are. There is no doubt, however, that **these conceptualizations are as figurative and embodied** as those of the older macroscopic physics.

In summary…

…much remains to be done if we really want to understand how we understand nature, and if we want to transform this knowledge into a consistent, encompassing, efficient, and humane pedagogy of modern science.