Meaning in Nature — From Schematic to Narrative Structures of Science

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If we listen to nature we hear her telling stories and when we speak about her we do so in the form of stories. We may not be aware of this but we can find the basic structures of schematic, metaphoric, and narrative thought common in human life even in the most formal of scientific accounts. My essay is about these structures of the human mind, about their development, and my claim that we can identify them equally in common as well as scientific thought. As a corollary, I will argue that science education can make use of stories for small children to slowly and carefully construct the basic concepts needed to make sense of nature and understand science. Story structure develops as learners get more mature and it evolves into the narration of formal models of natural phenomena.

In Section 1 I will briefly describe the philosophical background of our approach to science education which is discussed in the present volume. Our point of departure is best described by a dynamical systems view of human development and the assumption of an embodied mind. Section 2 is devoted to a presentation of image schematic and metaphoric structures of natural science. The presentation is based upon a short review of some aspects of cognitive linguistics suggesting that thought and language make use of figurative structures (image schemas and metaphoric projections).

The theory of schematic and metaphoric structures of the human mind is applied to a large-scale figurative structure—called the Force Dynamic Gestalt—which we humans seem to derive from experience in order to make sense of a vast range of phenomena (Section 3). We will see that we use the same kind of structure to reason about justice or electricity. This shows that formal scientific thought has the same figurative roots as every-day thought.

Sections 4 and 5 are devoted to an extended model of narrative science teaching that can be used to develop a curriculum starting with the very young in kindergarten or primary school and going all the way to university level.

1. Evolution of the Embodied Human Mind

How can we best learn about the natural world around us? How do humans create a meaning of the experience of nature? Two very different answers emerge depending upon how we view human nature and science. If we think that science is a representation of a truth beyond the human soul, we will turn to books that describe this truth and we will try to learn the literal propositions contained in these books. This typically means that if we want to include science in early education, we must somehow transform its propositions and reduce them so that a child can have access to what we say. According to a widespread interpretation of Piaget's theory (Piaget, 1952) this entails stripping science of its abstract expressions to make what we say and do concrete—children are considered concrete thinkers in early life who have access to only those things they can directly experience in the outside world. The path toward real science is then one of growing abstraction of literal propositions about the world.

If we believed, however, that learning and understanding are the results of an organism— a body with a brain—interacting with its physical-social environment (Maturana and Varela, 1987; Thelen and Smith, 1997; Gibson, 1966, 1979), we could see that the function of the nervous system and the body of an organism is to form abstractions of the recurring interactions between this organism and the world. We would see our mind growing by creating the most basic and most general-purpose shapes and abstractions (Arnheim, 1969) that help us function and survive. We could then look for forms of meaning and understanding of a general nature growing in us in the course of life—as a result of perception and action. Abstraction would be the beginning of our embodied mental life, not the final product of a long education.

If we consider thought to be a biological and social and cultural function, we may accept that the human mind evolves in both the species and in the individual (Donald, 1991; Egan, 1988). We might be inclined to believe that our human nature and our environment afford us structures of understanding that are used equally in every-day life and when we create a science. In other words, we might consider the possibility that reasoning in every-day life and in science are not utterly distinct. Most importantly for my argument, we might be ready to entertain the idea that even a very young child has already developed abstract schematic and metaphoric structures (Mandler, 2004; Lakoff and Johnson, 1980; Johnson, 1987, 2007) from which conceptualizations in formal science grow (Fuchs, 2007). As children learn they add a repertoire of sense-making capacities (Egan, 1997) to the base of schematic and metaphoric thought that, if properly nurtured, can allow them entry into the world of formal science.

The embodied mind. A modern way of expressing the point I have been making in the previous two paragraphs would be to say that our mind is *embodied*. Philosophy (Dewey, 1925; Johnson, 1987, 2007; Lakoff and Johnson, 1999), psychology (Mandler, 2004), linguistics (Talmy, 2000; Lakoff and Johnson, 1980, 1999; Gibbs, 1994; Hampe, 2005), robotics (Pfeifer and Bongard 2007; Chemero, 2009), brain science (Tucker, 2007; Damasio, 1999), anthropology (Donald, 1991), and many more disciplines have joined forces and have opened up a new approach to the study of human nature. They have provided and continue to provide new forms of understanding of how we learn and make sense of the world around us. Since this field of study is so wide and the disciplines adding weight to it are so many and so diverse, I can only refer to the small part that has been most influential for my study of the conceptual structure of the physical sciences and our proposal in this book for a narrative approach to science teaching.

Cognitive linguistics. Cognitive (Evans and Green, 2005; Geeraerts and Cuyckens, 2007) and functional (Halliday and Matthiessen, 2004; Lemke, 1990) approaches to linguistics can help us see science and language use in science learning from a new perspective (see Section 2). To make a long story short, the concept of the embodied mind and the results of cognitive linguistics demonstrate the importance of human imagination for thought—human thought is *figurative*. This allows me to argue that image schematic and metaphoric tools of the human mind provide the basis for conceptualizations in science. Science is not the representation of external truths, it is the representation of the products of our imagination engaged with experiences of nature.

Development of the mind. While not directly informed by the thesis of the embodied mind, the following accounts of the evolution and development of the human mind—both in phylogeny and in ontogeny—in no way contradict this thesis and add in important ways to our understanding of human learning. The work of Donald (1991) on the evolution of the mind of the human species and of Egan (1988, 1997) on developmental stages of an individual opens up an evolutionary perspective upon what has been achieved in embodied cognitive science. Moreover, it shows the importance of the social environment for the origin of the human mind, an aspect that is somewhat underdeveloped in cognitive linguistics.

The work of both authors demonstrates the importance of the development of language and forms of language usage from pre-linguistic communication through spoken language to early and progressively more formal literacy involving technological tools such as writing and printing (Ong, 1982). Interestingly, their research and that of others working on developmental theories of the human mind point to the singular importance of orality for the most basic forms of understanding found in human conceptualizations of the world. Egan (1988) shows that a tool used in oral (mythic) societies for meaning making—the schema of *polarities* such as GOOD <–> EVIL, COURAGE <–> COWARDICE, LIGHT <–> DARK, COLD <–> HOT—is a basic element for structuring narratives. In Section 3, I will show that this figure of thought is an element of a larger pervasive figure—the *Force Dynamic Gestalt*—which appears in everyday thought as well as in scientific conceptualizations. Human language demonstrates that there are three main aspects of this Force Dynamic Gestalt (FDG): *intensity*, *quantity*, and *power* or *force*. The FDG is a structure we actually apply to a vast number of phenomena ranging from pain or justice to what I call the *forces of nature*—fluids, electricity, heat, substances, and motion. (Note that I do not use the word *force* in the sense of a force in mechanics.) Logical and formal reasoning about these phenomena requires learning to differentiate the aspects of the FDG.

Narrative understanding. This brings me to theories of narrative understanding. Much work has been done in this field (Mandler, 1984; Bruner, 1987; Egan 1986, 1988), again without being directly guided by theories of the embodied mind. Stories have a general structure called story grammar or story schema (Mandler, 1984) typically consisting of a beginning that is set up by problem created by a polarity which is then elaborated and finally solved (Egan, 1986; but see the discussion of an alternative story structure in native American stories, St.Clair, 2000). Stories build upon, engage, and strengthen affective meaning (Egan, 1986) rather than making use of paradigmatic thought (Bruner, 1987). Put simply, stories deal in human affairs.

This may give the impression that stories create an environment that would be difficult to use directly for science instruction. However, in Section 4, I will integrate knowledge gained from the various sources discussed in this section—evolution, embodiment, and narrative—to suggest an extended model of narrative. This model can be applied to develop a path in science education based upon the evolving language capacity of a child. We will show in this volume that an understanding of nature can be formed if we begin with stories that include the schema of natural characters—the FDG of the forces of nature—and then slowly develop a more formal understanding of these characters by making use of the growing sense of the cognitive tools of orality and literacy.

2. Figurative Language: Image Schemas and Metaphoric Projections

We tend to accept the idea that much of human language—and probably most of what we say and write in science—must have a literal meaning. There must be a direct one-to-one relationship between what we say and structures in the universe. How else could we ever come up with truths about nature? Science is the history of the discovery of these truths—laws that exist in nature independently of the human mind.

Functional linguistics in general (Halliday and Matthiessen, 2004) and cognitive linguistics in particular (Evans and Green, 2005; Geeraerts and Cuyckens, 2007) suggest that this is not so. Language and human thought are not literal (Gibbs, 1994). They are largely figurative, making use of figurative structures such as image schemas and metaphors that have been given new meaning in cognitive linguistics (see Contini, this volume, for more details on figurative language and imagination).

Talking about cold: a Winter Story. Let us consider a concrete example of a common-sense description of thermal processes. The example is from a short story written for small children (Fuchs, 2010a):

> *But in Little Hollow, things were different. The cold of winter knew a good place where it could do its job of making everything and everybody cold much more easily. It could flow into the hollow where the town had been built. It could collect there [...] More and more cold could collect in Little Hollow, and it got colder and colder as the winter grew stronger. The temperature fell and fell.*
>
> *The people of Little Hollow [...] knew that the cold would find its way into their homes if they were not careful to close windows and doors. The cold could even sneak in through tiny cracks between walls and windows, so the people had learned to build their homes well to make it hard for cold to flow in. [...] At times when much cold had collected in their town the fires in the furnaces had to work very hard to fight the cold. The people in their homes made sure that the heat produced by the furnaces would always balance the cold so that their homes felt comfortably warm.*
>
> *For the children of Little Hollow, the cold of winter was not so bad. [...] But even for them, the thick cold of winter had mischief in mind. It went into the snow lying on the ground to make it very cold as well and this made the snow drier and harder to work with. ...*

Two things are important here. For one, the meaning of metaphor is not found in the somewhat flowery and child-centered language, nor in the comparison of cold to an almost human character. Secondly, the metaphors which we will find here are the same which we would use in a formal scientific account of the same phenomena.

In this little story, metaphors are found in expressions we normally consider standard or ordinary language. Take the expressions "…cold would find its way into their homes" and "…build their homes well to make it hard for cold to flow in" which are so ordinary and properly scientific at the same time (Fuchs, 2007, 2010b) that we might be inclined to call them examples of literal language. What else should cold do if not flow into a warm space if not properly hindered? Since cold is hardly a substance that can flow and whose flow can be hindered or aided, the language used must be figurative: it is an example of the conceptual metaphor COLD IS A FLUID SUBSTANCE. (see Table 1 for more examples found in the Winter Story). Clearly, our mind and our language do not offer us alternatives—this is how we think and talk about cold (or heat).

Table 1: Metaphors for Cold in the Winter Story

METAPHORS	LINGUISTIC METAPHORIC EXPRESSIONS
COLD IS A POLE OF A POLARITY	The people in their homes made sure that the heat produced by the furnaces would always balance the cold so that their homes felt comfortably warm.
THE DEGREE OF COLD IS A (VERTICAL) SCALE	The cold of winter knew a good place where it could do its job of making everything and everybody cold… And it got colder and colder as the winter grew stronger. The temperature fell and fell.
COLD IS A (FLUID) SUBSTANCE	It could flow into the hollow… More and more cold could collect in Little Hollow… The cold could even sneak in through tiny cracks between walls and windows…
COLD IS A POWERFUL AGENT	It went into the snow […] and this made the snow drier and harder to work with. The fires in the furnaces had to work very hard to fight the cold.

Conceptual metaphor. It is important that we see metaphor in a new light lest we never understand the figurative structure of science. Generally speaking, metaphor is a projection (transfer) from a source domain to a target domain. Kövecses (2002) has listed the important differences between the classical and conceptual theories of metaphor (Table 2). Whereas, traditionally, metaphor has been considered an embellishment of language that makes use of comparisons of a source and a target for rhetorical and poetic purposes which we can do without by replacing it with literal expressions, metaphor in cognitive linguistics is considered conceptual. Metaphoric projections are a necessary and ordinary element of human language and thinking. They are a largely unconscious function of the human mind that projects knowledge structures of a source domain onto a target domain thereby structuring the target domain in terms of the source. In general, there is no preexisting similarity between source and target; rather, the metaphoric projection creates a similarity—it makes two domains similar to the human mind.

Note that a particular expression ("cold flows into the home…") is not the metaphor, it is a linguistic example for the actual underlying metaphor (COLD IS A FLUID SUBSTANCE). There are many possible—including new and poetic—linguistic expressions for a given metaphor.

Moreover, and very importantly, a single target domain may give rise to many different metaphors using different source domains, and a single source domain may be applied to structure many different target domains. To give examples, the source domain COLD is structured differently in terms of the different sources fluid substance, vertical scale, powerful agent, among others (see Table 1). On the other hand, the source domain fluid substance is used in physics to structure such targets as heat, electricity, chemical substances, quantity of motion, or spin (Fuchs, 2010b).

Table 2: Metaphor in traditional theory and in cognitive linguistics

TRADITIONAL METAPHOR THEORY	CONCEPTUAL METAPHORS
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 though and reasoning.

The present description of conceptual metaphor only uses examples from the sciences and barely scratches the surface of this exciting and vibrant field of study. Clearly, conceptual metaphors are not found just in science, they are a ubiquitous phenomenon of human language and thought. I have chosen examples from the natural sciences since this is our concern in this volume and because we normally do not see—even refuse to see—the metaphoric figurative nature of a description of natural phenomena in science.

Image schemas. In metaphor, we project—often unconsciously—some knowledge structures (the sources) upon others (the targets). We see the purpose of the conceptual metaphor as shining light upon the target. The question arises how knowledge can be grounded. Where does our understanding of the source stem from? Is there such a thing as basic metaphor? Are there fundamental source domains?

Johnson (1987) and Lakoff (1987) introduced the concept of a fundamental schematic structure of the human mind they call *image schemas* (see also Arnheim, 1969). This notion has been and still is subject to intense research (Hampe, 2005). Simply put, an image schema is an experiential gestalt (an abstraction) that results from recurrent interactions of an individual (body and brain) with its physical and social environment. Image schemas are relatively simple but contain enough internal structure that they can be used for reasoning, as when they are projected metaphorically onto a target. The term image does not imply visual or graphical images but rather points to *imagination*. We can understand the power of the human imagination as the result of the existence of image schemas and their metaphoric projections onto more complex targets.

A large number of image schemas have been identified in cognitive linguistics: scale or polarity, up-down, in-out, container, path, verticality, object, (fluid) substance, balance, compulsion, restraint, enablement, blockage, diversion, attraction, manipulation, merging, collecting, part-whole, mass-count, link, process, cycle, state, to name just some of the most important (Johnson, 1987; Croft and Cruse, 2004). We can easily identify image schemas and their projections in the metaphors for cold listed in Table 1.

3. Forces of Nature and the Force Dynamic Gestalt

Image schemas are relatively “small” abstract schematic structures. There are more complex phenomena that can be structured metaphorically by using several to many image schemas or even larger-scale source domains. They nevertheless lead to experiential gestalts just like simple interactions lead to image schemas. Such gestalts have complex internal structure but, at first encounter, as an experience, they are as simple and unified as any gestalt should be. Witness the following example:

> *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. (Sassi, 2006, reported in Fuchs, 2007)*

What the boy reports here is the existence of experiential gestalts: cold and heat. We all know cold or heat when we see them, we all know when we have a thermal experience. Cold or heat are simple abstract wholes in this sense. However, the gestalts that appear in Alex’s story have an interesting recurring structure: quantity (size), intensity (such as hot, very hot…), and power (the ability to cause something) are intertwined in the description of the properties of snowmen and dragons. I call this figurative structure a *Force Dynamic Gestalt* (FDG).

The FDG of justice. The structure of the gestalt that has been laid out is apparent in a multitude of phenomena such as arguments or ideas, justice, the (economic) market, water, heat, or electricity, just to name a few. They all seem to have one thing in common: at a deep level they are forces or powers, concepts that are introduced to explain how things happen and how one thing influences another. Here I would like to describe the structure somewhat more formally, using ideas from cognitive linguistics. To gain a perspective from outside of the natural sciences, I want to collect a few expressions used to speak about justice (Fuchs, 2007):

(1) I don't think there is much justice in the world.
(2) I have always found that mercy bears richer fruits than strict justice. (A. Lincoln)
(3) The healing power of justice.
(4) Hence justice hinders theft of another's property.
(5) Create a terrible imbalance in our criminal justice system…
(6) He got the justice he deserved.
(7) With this move we are coming closer to true justice.

The first expression shows justice as an entity, the next shows the quality or intensity of justice. 3 and 4 speak of the power or force of the gestalt, and 5 introduces the image schema of balance. The last two expressions demonstrate something very interesting. In metaphor theory, systems of dual metaphors have been identified (Lakoff and Johnson, 1999). One set of metaphors is the figure-ground reversal of the other. In 6, justice is the figure and the person receiving justice is the ground. Expression 7 is reversed: we are the figure that is moving with respect to justice that represents some kind of landscape or path in or along which we move.

A beautiful and detailed analysis of the schematic and metaphoric nature of an experience of music is given in Johnson (2007, Chapter 11). Johnson does not introduce the notion of an FDG, but clearly what he creates there is the description of such a structure.

FDG of the forces of nature. In the physics of the early nineteenth century, there is a beautifully worked out example of a perfectly differentiated FDG of heat. This is Sadi Carnot's *La puissance motrice du feu* (1824). In his words,

> *According to established principles at the present time, we can compare with sufficient accuracy the motive power of heat to that of a fall of water […]. The motive power of a fall of water depends on its height and on the quantity of the liquid; the motive power of heat depends also on the quantity of caloric used, and on what may be termed, on what in fact we will call, the height of its fall, that is to say, the difference of temperature of the bodies between which the exchange of caloric is made.*

We can see the figurative structures identified in the case of justice in Carnot's description of heat and they appear as well in the models of the phenomena of fluids, electricity, chemical substances, and motion (Fuchs, 2007, 2010b). These are clear-cut cases of the conceptualization of the extensive entity associated with a force of nature as a fluid substance, of the intensity as a vertical scale, and of the application of force-dynamic structures (such as conductances or resistances). The phenomena are associated with power—they cause things to happen— and with balance or equilibrium. Moreover, an important quantitative relation between the three main aspects (quantity, potential difference, and power) has been postulated: the power of a phenomenon is proportional to the flow of the quantity and the potential difference through which the quantity flows. Carnot's image of a waterfall explaining the working of heat in a heat engine is the archetype of a model of physical processes (see the contribution of Corni in this volume for details on a physics of the forces of nature).

Mythic roots of the Force Dynamic Gestalt. We can find the figure of thought developed from a differentiation of the Force Dynamic Gestalt of phenomena in some of the oldest historical accounts. As mentioned before, polarities are a prominent element of mythic understanding. For example, this element represents much of ancient Egyptian thought and culture, both in situations of every-day life and of spiritual affairs. In Egyptian and Babylonian cosmologies, the world is created by differentiation from undifferentiated chaos, by the sky separating from the Earth. Life continues as long as the tension between the two is maintained or, as the Egyptians said, the difference allows maat (loosely translated as “that which is right”) to flow. In Egypt, it was the god Shu (air) that supports Nut (heavens) from falling to Geb (Earth). In Babylonian mythology, it was the wind that separated heaven and earth. Dynamics is rooted in the tension between the poles of the polarities that govern nature and society.

Analogy and conceptual integration. The foregoing discussion lets me introduce the concept of analogy between different forces of nature as a (partial) bi-directional mapping made possible by the fact that the domains or spaces of different concepts (such as fluids, electricity, or heat) are structured similarly or even equally (Fig.1; see Fuchs, 2007, Section 2.4 for details). In terms of conceptual integration (blending) theory (Fauconnier, 2001; Fauconnier and Turner, 2002), the spaces (domains) of our concepts share the same generic space. In our case, the generic space may be considered the totality of the schemas and structures projected metaphorically onto the spaces of the various concepts.

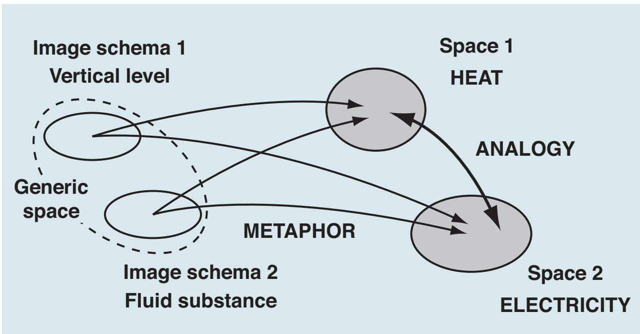

Figure 1: Two phenomena such as heat and electricity acquire similar structure due to metaphoric projection of the same schemas upon each domain or space. This allows us to map elements and structure between the spaces of the phenomena. Note that, in general, the mapping is bi-directional. We can understand thermal phenomena in terms of electric ones, and vice-versa. (Fuchs, 2007)

4. Stories and the Character Schema

Much has been researched, written, and said about narrative understanding in general and stories and story telling in particular. For my purpose here it is important to note that stories are considered to add a human dimension to an otherwise “inhumane” science. By and large, we experience science as trying to cleanse its results from the vestiges of human emotions so that the pure intellect can shine through. Maybe as a reaction to how we commonly see the natural sciences, we tend to think of stories and story telling as an opposite to the desiccated intellectual products created—or rather found—in these fields. Stories provide what the sciences cannot. Let us see if this view is justified.

Narrative and paradigmatic modes of thought: Dichotomy or continuum? Bruner (1987) has taught us to see important aspects of *narrative understanding* and stories and he sets them apart form scientific or, as he calls it, *paradigmatic thought*:

> *“There are two modes of cognitive functioning, two modes of thought, each providing distinctive ways of ordering experience, of constructing reality. […] Arguments*

convince one of their truth, stories of their lifelikeness. [...] A good story and a well-formed argument are different natural kinds." (Bruner, 1987, p.11)

To appreciate the importance and power of stories for learning, we should be well aware of the character of stories and it may help if we realize how they are different from typical practice, arguments, and thought in the natural sciences (see Table 3).

Table 3: Bruner's distinctions between narrative understanding and paradigmatic thought

NARRATIVE UNDERSTANDING	PARADIGMATIC THOUGHT
Stories convince of their lifelikeness	Arguments convince of their truth
…establishes not truth but verisimilitude.	…verifies by eventual appeal to procedures for establishing formal and empirical proof.
Causality implied in narrative […] leads to a search for likely particular connections between two events.	Causality in science […] leads to a search for universal truth conditions.
Must conform to logical consistency but can use violations of such consistency.	Cannot use such violations.
Criteria for judging goodness of a story.	Criteria for judging correctness of a logical argument.
	Scientific hypotheses start their lives as metaphors, but their power at maturity does not rest upon their [metaphoric] origins.
How do we come to endow experience with meaning, which is the question that preoccupies the storyteller.	Science consists principally of the falsification of hypotheses.
	…attempts to fulfill the ideal of a formal, mathematical system of description and explanation…and deals in general causes.
Imagination leads to good stories, gripping drama…and deals in human or human-like intention and action and in the vicissitudes that mark their course.	Paradigmatic "imagination" is not the same as the imagination of the novelist or poet.

This rather harsh distinction between the two modes of thought has been picked up in recent research on the use of narrative in science teaching (for some of the research in this field see Kubli, 2001, 2005; Klassen, 2006; Metz at al., 2007). It sees the story form as helping with motivation for the subject and leading to engagement of emotional intelligence on the side of the learner. It is not surprising that historical accounts of science—the lives and achievements of important scientists—are used most frequently when the inclusion of the story form in the science classroom is discussed. While there may be a hint of an argument in the literature that engagement of more than just formal intellectual powers may somehow also lead to a better understanding of the science itself, it is not clear at all how this is supposed to happen.

We should not deny important differences between the function of a typical story and a scientific argument, but there are too many similarities between narrative understanding and paradigmatic thought to ignore. For brevity's sake, let me refer to only one point brought up in the list of Table 3. It is said that the question preoccupying the storyteller is how we come to endow experience with meaning. This is no different in science: the meaning of a scientific argument is paramount if we are to understand it. According to what I have said in Sections 2 and 3, the meaning of a conceptualization in science grows from the schematic and metaphoric structures used in an argument and these are the same figures of thought applied to many other aspects of life. In other words, we have good reason to believe that stories and theories or models in science are not two distinct species but rather form the ends of a spectrum of how humans create meaning.

Story schema and character schema. At first glance, Egan's (1986, 1988) discussion of the issue of narrative and stories is not that different from Bruner's (1987). However, he makes points concerning the structure of stories that allow for a somewhat more liberal view of the relationship between stories and the content or results of science. First, the developmental framework outlined by Egan demonstrates rather clearly how stories are a tool for building general intelligence (i.e., how they fit into the larger scheme of the acquisition of cognitive tools): they are an integral part of the use of language at an early age reflecting forms of understanding common in mythic (oral) societies. This type of understanding is an integral component of later forms of thought. Secondly, story structure is, to a large degree, the result of using polarities or binary opposites (Egan, 1986, and this volume): a polarity is the source of a conflict around which a story can be constructed and that is solved or satisfied in the end. A polarity is the resource of a story that opens the door to affective meaning and introduces the characters that form the story:

> *"Clearly stories are concerned with affective responses. A good story-teller plays our emotions, as a good violinist plays a violin. We resonate with the rhythm of the binary conflict, the events that carry it forward, and its resolution." (Egan, 1986, p.29)*
>
> *"[...] the binary opposites that underlie our story serve as criteria for the selection of the 'content'—the characters and incidents—which form the story." (Egan, 1986, p.27)*

For a lesson plan on the subject of heat, Egan proposes to use the opposition HEAT AS HELPER <–> HEAT AS DESTROYER rather than the polarity HOT <–> COLD (Egan, 1986, p. 98). We understand the meaning of this choice: HEAT AS HELPER <–> HEAT AS DESTROYER lends itself to creating a story of the human drama of the use of heat. It sets up the central conflict that drives the story from beginning through its middle to its resolution thus creating the story schema.

If we analyze the Winter Story (see Section 2), we see that it follows the same approach: there is the drama of the people of Little Hollow living through a winter—created by the polarity COLD AS HELPER <–> COLD AS DESTROYER —and this drama pretty much gives the story its large-scale structure. However, at the same time there is a second binary opposition for cold at work in the narrative—the polarity HOT <–> COLD. It leads to a particular character—cold as a force of nature—that forms part of the smaller-scale structure of the story.

Despite the fact that the two choices of polarities work at different scales of the story, they both introduce characters that are forces conceptualized by the elements of the Force Dynamic Gestalt. Maybe the two are not so different after all. The forms of reasoning employed in both are the same, namely, reasoning and logic following from the internal structures of the image schemas and their metaphoric projections (Johnson, 1987). In summary, it appears to make sense to postulate a *character schema* for narratives in addition to the story schema. Cold initiates the human drama but is also a gestalt in our Winter Story that follows the character schema (of a force of nature). As we have seen in Sections 2 and 3, learning about the gestalt of cold (or heat) leads to good science. Narrative and paradigmatic thought do not seem to be so far apart, after all.

We can go even a step further. While in the Winter Story—and the typical stories we tell our children—the large-scale structure is created by opposites that open up a human drama, humans are not needed. We can construct the story schema for a drama of nature. We only have to set a slightly higher goal for a science curriculum than just learning about the propositions of science and ask what the forces of nature mean for nature itself. A theme that lends itself quite naturally to such a story is the drama of how water and ice sculpted our land through the ice ages of the last several tens of thousandths of years—and there are countless such themes. A story of this kind uses opposites like the ones discussed here for both the story and the character schemas without necessarily involving human drama.

The gestalt of a story. Still, if we just focus on the content of science, why should we tell stories? Is there any need or sense in putting the forces of nature as narrative characters into stories or is it enough to use good figurative language in our scientific arguments? The question can be restated as follows: in what sense is a story more than the sum of its constituent parts, expressions, propositions, schemas (such as the character schema), etc.?

A story is actually a whole, an experiential gestalt of its own. If you think of it, one way of analyzing a story is in terms of the Force Dynamic Gestalt. A story can be big or small (quantity), it can be well or badly told or it can be exciting or boring (quality), and it can definitely be powerful. It has aspects and elements but they never add up to the story itself. A story creates connections that are not part of the elements, it has a flow or dynamic, it provides a resolution and engages readers in important ways (with their images, interests, hopes, fears…; see Egan, this volume). A good and well presented model of a physical system and its processes is an example of a story and we know that a model is more than the sum of its propositions. It brings satisfaction, resolution: we understand. To reiterate the main point, a story is a simple whole, a unity, a gestalt.

Literacy and the development of tools of formal thought. Stories are the invention of the oral mythic mind (Egan, 1988). We do not have to be able to read and write to appreciate, understand, and tell stories. So what is the meaning of acquiring literacy for the mind of a young person? Obviously, literacy adds new capacities, new cognitive tools (Egan, 1990; Ong, 1984; Di Martino, 2011). If it is true that science can start in an oral world with stories, it is also true that it could never achieve what we expect of it without the tools of writing and reading. I will turn to this question briefly in the last part of my contribution where I want to draw some general conclusions for the classroom.

5. Teaching Science

The outline of the theory of how we understand nature presented here allows for some conclusions regarding a science curriculum that starts in early education. Here are a few points worth considering when we build a new curriculum.

Polarities, imagination, and fantasy. When we start talking about forces of nature in the early years of school (including kindergarten), a particular problem or question arises. How do children arrive at a notion of *agent* or character of a force (by this I mean the quantitative or substance aspect of the Force Dynamic Gestalt)? Is this a totally natural or automatic development we do not have to worry about? Or do we have to make a conscious effort to introduce, for example, *heat as an agent*? We may argue that the cognitively natural element of the FDG is the aspect of quality or intensity associated with the polarity that creates a particular force (HOT <—> COLD in the case of heat). The quality of a phenomenon is perceptually foundational. Children certainly know about hot and cold without us having to add too much to it. But what about heat?

We may use Egan's (this volume) notion of the origin of fantasy. Fantasy is the particular cognitive tool that develops as the result of a few special polarities such as LIVING <—> DEAD or NATURAL <—> ARTIFICIAL/CULTURAL. In this case the mind of a child leads to the creation of characters mediating between the poles: ghost in the former example, talking bears in the latter. Fantasy seems to be the tool that allows us to introduce objects/characters/agents to complement the quality/intensity aspect of the polarity. I am inclined to call the conceptualization of characters/agents such as quantities of heat, electricity, light, cold, motion, etc., an act of fantasy. In teaching, we have to be a little more conscious about how to develop these agents.

Learning to differentiate the FDG of forces of nature. The foregoing discussion points to an important aspect concerning teaching and learning science. If we wish to understand the root concepts of physical science underlying the forces of nature such as fluids, electricity, heat, and motion, we have to learn to differentiate the aspects of the Force Dynamic Gestalt of these phenomena. This must be a conscious effort: conscious knowledge of the existence, meaning, and interrelationships of intensity, quantity, and power (plus related schematic structures) of these forces is required. Since a comprehensive and transparent differentiation is not achieved in every-day life—it is hardly necessary there—and since advanced courses in the physical sciences are rarely clear and deep enough on this point, we need early education to help us reach this goal. The story is the natural vessel for introducing the FDG of forces of nature.

Evolving story form, literacy and propositional thought. Starting with simple stories that build up a story schema of human drama and also introduce forces of nature through the character schema, we can evolve the narrative form in the course of primary school and beyond. Early stories should slowly build an awareness of the power of the FDG. Children should listen to stories and tell their own. Language exercises can support good speaking and writing as a support for later more formal accounts.

As children's minds become more adept at using additional tools—particularly the growing capacity of literacy—we can (1) increase the proportion and scope of the character schema and let the characters and their inherent logic become stronger and more prominent, i.e., make the stories more formal, and (2) add details about nature that children recognize more and more clearly as their sense of reality grows, i.e., make the content of stories richer and more realistic. Egan (1990) has taught us to see this sense of reality as one of the first important consequences of the development of literacy. The tools of literacy (Di Martino, 2011) added through the years—list making, graphs, maps, more complex language and grammar—will make it possible for a young person to increasingly deal with the propositional form of the results of science (without at the same time falling into the trap of nominalization common in scientific language; see Halliday and Martin, 1993, and Lemke, 1990). A particularly important result of the conscious knowledge and differentiation of the FDG is the development, in later primary school, of the energy concept out of the aspect of force/power (see Corni, this volume).

However, stories are not just for early science education. I did not show in this essay that formal models in intermediate to advanced science courses are based on narrative. The foregoing discussion should convince us that the physical sciences are figurative at heart and that these figures will be part of a curriculum through all levels and years.

To summarize the most important point of this essay, let me say this. Science uses propositional forms but it is not constituted by propositions. Rather, it creates a world of fantasy based on imagination. Its figures are products of the imagination of the human mind. More than anything else, this recognition should let us accept that science is actually narrative. The story form is not alien to the science we have created. If we accept this, we have a chance of putting human nature back into our descriptions of nature. We will become good storytellers capable of endowing our tales of nature with meaning.

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