Pseudo-science and Metaphoric Operativity: Making the Case for a Cognitive Model of Scientific Change

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Abstract. Pseudo-scientific and 'fantastic science' beliefs have long been recognized as a significant impediment to the aims of science literacy among students and the general population. Nevertheless, many philosophers, historians, and sociologists of science as well as psychologists and scientists believe that aspects and dimensions of what is today labeled pseudo-science has provided (and still provides) the creative and generative foundation to science and scientific knowledge through metaphoric as opposed to logical operativity, because it has far fewer cognitive constraints than 'normal' science. The purpose of this paper is to provide an initial attempt to model the process by which a pseudo-scientific commitment (by today's standards) evolved into and contributed to a truly scientific commitment, and to demonstrate how cognitively-based changes in epistemological standards were necessary for this transition to occur. Specifically, this paper will model the development of the concept of syphilology from the mystical to the pathological to the purely etiological described by Fleck (1935/1976) in his now classic book *Genesis and Development of a Scientific Fact* from a cognitive perspective.

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There is neither a first nor second author for this work, as this work is a co-authored interdisciplinary work to which each author has contributed equally.

Background

Pseudoscientific and 'fantastic science' beliefs have long been recognized as a significant impediment to achieving the aims of science literacy in both students and the general population (Keselman, Kaufman & Patel 2004; Losh, Tavani, Njoroge, Wilke & Yigit 2004; Preece & Baxter 2000). *Pseudoscientific beliefs* have been referred to as truth claims that prima facie appear to be scientific but that 'can be shown to fail one or more crucial tests of rigorous scientific examination (and therefore can be rejected with near certainty)' (Eve 2004, p. 2). Similarly, Shermer defines pseudo-science as 'claims presented so that they appear scientific though they lack supporting evidence and plausibility' (Shermer 1997, p. 33). *Fantastic beliefs*, on the other hand, 'refer to beliefs about science that are unlikely to be supportable by any *conceivable* scientific means, but where nonetheless these beliefs are not easily proved to be false beyond *any* doubt (Eve 2004, p. 2 emphasis added). Fantastic beliefs would be harder to change, we believe, than pseudoscientific beliefs. However, following the convention of Eve (2004) and for the sake of brevity, each of these beliefs will be referred to here as pseudo-science with qualifying distinctions made where necessary. To some degree and by contemporary scientific and psychological standards, pseudoscientific beliefs can be thought of as reasoning 'errors' where a student or individual's epistemological standards (i.e., the criteria used to judge the validity and meaningfulness of knowledge claims and experience) are inconsistent with the epistemological standards of scientists and other critically minded individuals and disciplines. They could also be seen as partial beliefs, beliefs 'in formation' (or unexamined beliefs), beliefs to which reasoning skills have not been applied or beliefs formulated prior to the acquisition of more than elementary reasoning skills. Currently, however, most work on this topic has focused on reasoning errors.

Reasoning errors and their associated beliefs are an important issue related to student misconceptions in science (as well as mathematics and other content areas) and the vast literature that informs this area of research. However, pseudo-science research is concerned not only with identifying and remedying misconceptions per se, but also with trying to understand the methods and warrants people and students use in determining the quality and justifiability of knowledge claims. Those intended on debunking pseudoscientific beliefs and attenuating irrationality (referred to as "skeptics") look to do so by using a systematic and scientific approach "that involves gathering data to formulate and test naturalistic explanations of natural phenomena" (What is a Skeptic 2003, p. 5). However, even modern skeptics recognize that the boundary between science and non-science (known as the demarcation problem in philosophy) is extremely fuzzy and complex evading a precise semantic definition (Shermer 2001). Further, the distinction between "proto-science" and its influence on transitional stages that characterize the maturation of a scientific theory and pseudo-science is not well understood. Indeed, the history of science reveals that many proto-scientific and pre-scientific ideas were pseudoscientific by today's standards.

This shift and shifting of 'sacred' knowledge to 'profane' knowledge and 'profane' knowledge to 'sacred' knowledge is a very difficult phenomenon and process for people to understand (see Carifio 1976) who do not have a tentative, probabilistic and revisionary view of scientific knowledge and the appropriate epistemological standards to accompany this view. The problem, however, is even more difficult and complex than this classical representation of the problem. We live in a century of 'fantastic' new discoveries and views which have come rapidly one after another in all areas and not just all areas of science (what one might call a knowledge 'inflationary' period to borrow from cosmology), *which both creates and breeds a climate of pseudo-science and fantastical and pseudo-scientific claims* similar to the way that the 16th to 19th century produced incredible frauds and hoaxes in the areas of art, books, antiques and other collectibles as they were the 'gems' and highly desired 'prizes' of this age. Further, as most radically new discoveries and views in science 'look like' pseudo-science in many ways, or 'profane' knowledge, quickly distinguishing between the two in the current climate is a lot more difficult to do than most people seem to realize and creates a general climate of what Kohlberg called 'the saint and the sociopath (or authentic or true and fraudulent or pseudo) problem' (Kohlberg 1981) relative to people discriminating the differences between Ghandi and Hilter as the higher order and more correct moral theory to accept and believe. Pseudo-scientific and fantastic science beliefs, therefore, are not trivial or local phenomena or problems, and studying wrong beliefs and why they are wrong may be more important than studying right beliefs and why they are right as error analysis has always been highly productive in science from Copernicus to Freud to Piaget to Thom. However, the process must be done in a manner that clearly and correctly depicts and portrays the 'boundary area' and 'event horizon' between the two and what can and often does happen in this very fuzzy and chaotic 'space'.

Without doubt pseudo-scientific beliefs per se are undesirable and problematic among students and the general population (and also scientists and those in 'science-based' professions), and one important aim of both general and science education is to help students achieve an understanding of basic science concepts, principles, and methods that are consensual with the existing core scientific community (as opposed to sub-communities and the fringe). However, it is important to point out that many philosophers, historians, and sociologists of science as well as psychologists and professional scientists believe that what is today labeled as pseudo-science has provided (and still provides) the creative and generative foundation to science and scientific knowledge because it has far fewer cognitive constraints than 'normal' science (Carifio 1976). For example, in one of the most thorough and meticulous case studies of the development of syphilology (the study of syphilis), Fleck clearly recognized the creative, generative and formative power of pre-scientific, 'fuzzy' and logically 'unjustifiable' ideas. As Fleck notes:

> Many very solidly established scientific facts are undeniably linked in their development, to prescientific, somewhat hazy, related proto-ideas or pre-ideas, even though such links cannot be substantiated (Fleck 1935/1976, p. 23).
>
> …a proto-idea must not be construed as a "freak of nature". Proto-ideas must be regarded as developmental rudiments of modern theories and as originating from a socio-cogitative foundation…The value of such a pre-idea resides neither in its inner logic nor in its "objective" content as such, but solely in the heuristic significance which it has in the natural tendency of development. And there is no doubt that a fact develops step by step from this hazy proto-idea, which is neither right nor wrong (Fleck 1935/1976, p. 25).
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> The acquisition of physical and psychological skills, the amassing of a certain number of observations and experiments, the ability to mold concepts, however, introduce all kinds of factors that cannot be regulated by formal logic (Fleck 1935/1976, p. 10).

Consonant with these views, the logical positivist Phillip Frank stated that:

> If we want to evaluate precisely and critically how firmly this philosophy [of science] is anchored in the ground of science, we must not ignore the extrascientific factors, but must analyze carefully the social, ethical and religious influences. Every satisfactory philosophy of science has to combine logic of science with sociology of science (Frank 1949, p. i).

Later Quine argued that rejecting the 'two dogmas of empiricism' (i.e., the cleavage between analytic and synthetic truths and the notion that all meaningful statements can be reduced to a logical statement about direct experience) leads to 'a blurring of the supposed boundary between speculative metaphysics and natural science' (Quine 1961, p. 20). In commenting on what he referred to as the pseudo-scientific (metaphysical/untestable) theories of Marx, Freud and Adler, Popper noted that he 'realized that such myths may be developed, and become testable' and that 'historically speaking all—or very nearly all—scientific theories originate from myths, and that a myth may contain important anticipations of scientific theories' (as cited in Schick 2000, p. 12). Although Popper was not concerned with the nature of this transition per se, he clearly recognized the fundamental importance of what Fleck describes as a proto-idea.

In accord with Fleck, Kuhn's descriptions of a 'paradigm shift' also address scientific progress and change more from a social-cognitive perspective versus a purely rational/logical perspective. Kuhn states that '…the transition between competing paradigms cannot be made a step at a time, forced by logic and neutral experience. Like the gestalt switch, it must occur all at once…or not at all' (Kuhn 1962/1996, p. 150). In reality, scientific theories or paradigms are far more complex and detailed than the overly simple stimuli in Gestalt experiments and examples, and the process of Gestalt switching for real complex concepts, views, theories and paradigms is rarely 'all at once or not at all', but rather is a chaotic and often unpredictable series of steps with seven league boots to the last 'Ah-ha' step, which requires a far greater number of steps for a mature scientist who has built up very complex knowledge structures than a young student or general lay person. Belief change is often just not that easy.

However, whereas many philosophers during Kuhn's era were concerned with the 'logic of discovery' (e.g., Popper 1969), Kuhn was concerned more with the 'psychology of research' (Kuhn 1970), although many of Kuhn's viewpoints and positions are prescriptive (a fundamental philosophical priority) as well as descriptive (a fundamental historical priority). Kuhn's view was certainly anticipated by Fleck and it polarized the philosophy of science community by creating a divide between the venerable philosophic schools of thought (such as logical positivism) that were concerned exclusively with the context of justification and a burgeoning 'postpositivist' view of science that was focused on the context of discovery and its psychological concerns. The admixture of these contexts is viewed by traditional philosophers of science (such as Frege and Popper) as a cardinal sin labeled *psychologism*, which is the 'contamination' of the normative and prescriptive intent and power of philosophy with the more subjective and descriptive discipline of psychology (something which might be called *Qualitative Philosophy* which is exactly what we are proposing here in its weak form). So in one sense, the work of Fleck and later Kuhn (and others) really provided an opportunity for a multidisciplinary approach to science studies by combing the logic and psychology of science. Many researchers have taken advantage of and used a 'weak' form of psychologism to successfully address problems in the philosophy of science (e.g., Thagard 1988) and psychologism plays a very important (albeit somewhat tacit) role in the nature of science movement in science education. It is instructive to note that much of the recent debate (last 75 years) between the logic and psychology of science can be viewed as a recasting of the differences between the ahistorical mathematical formalism of Descartes (1596-1650) and Vico's (1668-1744) philosophy of history which posits that to understand human experience is to understand the desires of the human will and emotions as well as the lineage of language, myth, fables, religion, law, and art forms—all of which come with and continually shape the economic and political landscape of the times and, most importantly, the dominant styles of thought (Kreis 2002). To Vico, Descartes reliance on concise, discrete and self-evident propositions (such as those provided by mathematics) and his total disregard for history and other dimensions of human experience provided nothing more than a naïve and unrealistic picture of human beings with no potential to describe the history and development of humankind. This point, and Vico's historical views in general, anticipate much of Fleck's thesis and the thesis of this paper.

More recently, and in keeping within a postpositivist perspective, Feyerabend's (1981) program of theoretical anarchism argued that prolonged success and stability in a scientific discipline is not a sign of success, but rather a sign of failure, because it becomes too precise, over-focused and restrictive to make 'significant' gains. This highly conservative state and condition serves to restrict any theoretical possibilities that are inconsistent with or outside the scope of the commitments of the existing discipline or Zeitgeist[1]. In this way, the discipline loses its ability to make certain types of gains because it becomes a product of its own 'rigidity'; i.e., highly mature and stabilized cognitive schemas, structures, personality and style factors. As will be discussed shortly, this 'tendency toward conservation' is an inherent feature of schemata as described by cognitive psychologists and is associated with a number of difficulties in problem solving including *functional fixedness* which is 'a tendency to use objects and concepts in the problem environment in only their customary and usual way' (Ashcraft 2002, p. 497). Feyerabend's counter to this problem is to adopt a program of theoretical pluralism, which includes the consideration of some theoretical possibilities (i.e., 'dark knowledge' which is in many ways similar to 'dark matter' in the universe) that may be considered pseudoscientific from the perspective of the dominant and established tradition. This position is unquestionably a viable approach and strategy when we consider—as Fleck recognized over seventy years ago—that many (if not all) of the most significant gains in the intellectual history of science are grounded in the iconoclastic, irrational, unjustifiable, extrascientific and fuzzy pre-ideas of the past. However, this approach also requires that there be a very good and strong *weeding function* built into the process that is activated periodically.

This weeding function is akin to what Quine refers to as a 'warping' (or shaping) of a man's 'scientific heritage' in response to a 'barrage of sensory stimulation' (Quine 1961, p. 46), which in Quine's view is a process that can be viewed as a pragmatic endeavor when executed in a 'rational' way. The link between rationality and pragmatism may play an important role (and perhaps even explain) the cumulative success (and weeding function) of science in different eras to some degree. However, the history of science and of scientific advances is also well characterized as an esoteric process, which in Quine's model opens the door to the role and function of irrationality, speculative metaphysics and what we call *metaphoric operativity* (defined below, and see Carifio 1975) in science and scientific progress. Along this same line, empirical research in psychology has demonstrated quite convincingly that people, including highly educated people, are only *partially rational* (some of the time) and are not always reliable Bayesian probability agents (Holyoak & Thagard 1997; Tversky & Kahneman 1981). Similarly, in his criticism of Piaget's model of intelligence, Carifio (1975) has made a strong argument that logical operativity alone cannot account for adaptive functioning and that new knowledge and insight is derived from metaphoric operativity, an aspect of cognition effectively ignored by Piaget (and most other cognitive psychologists).

The point to be made here is not that science should focus most of its attention on theories or ideas that exist on the fringe of established thought and rationality, but that there are critically important features associated with the development of scientific thought that cannot be reduced to merely logical, empirically justifiable and rational descriptions and characterizations during their initial formulation and development. For all the virtues of logical positivism, this was one of the key points that dismantled their original thesis and program. The brief examples from the history and philosophy of science described above (of which many more are available) serve only to argue the point that 'pseudo-scientific-like' ideas, views and beliefs have, in a historical context, significantly contributed to contemporary scientific thought and progress. Whether science should direct more of its resources on conceptual 'long-shots' based on this observation is a matter of theoretical economics and goes beyond the scope of this paper. It should also be pointed out that the overwhelming majority of pseudo-scientific ideas held by scientists and others are likely to atrophy over time, particularly if there is a strong weeding function and mechanism in place, such as conference paper presentations, debates, on-line community dialogues and so forth, all of which are mechanisms that can be utilized by students too. Nevertheless, the history and philosophy of science literature is replete with examples that suggest that this variety of 'unscientific' and highly exploratory and unjustifiable ideas is responsible for the fund of innovative ideas of which a rare few may, due to timing and circumstance, develop further under the critical and precise examination of scientific reason. Let us stress this particular point once again: the critical *few* that survive and blossom into a very different or revolutionary view, model, theory or paradigm, and for these critical *few* we must have and maintain some initial openness, tolerance and respect for the rest as premature closure and weeding too soon can stagnate the knowledge creation process in a given area. Also, one may be open, tolerant, respectful and skeptical at the same time; they are not mutually exclusive traits, states, or positions. Here again it appears that some sort of balance between the context of discovery and the context of justification and their corresponding epistemological standards may provide the most sophisticated, insightful and useful descriptions of the scientific enterprise.

By introducing students to the messy and often irrational and pseudoscientific beginnings of new theories and concepts derived from the history of science, students are allowed the opportunity to examine and reflect on how *epistemological standards change*. Indeed, researchers in science education recognize that the early 'naïve' views of scientists often mirror the views of students in the classroom (Monk & Osborne 1997). Helping students to realize that some of their own intuitive notions are consistent with some of the greatest scientists, philosophers and scholars in history, and allowing them to experience the developments in a particular scientific discipline over time may serve to elevate their personal epistemological standards. It would also allow them to observe the decision making processes that moved these scientists, philosophers and scholars away from their early 'naïve' views as well as to learn these kinds of decision making processes observationally and by modeling (see Bandura 1986). Similarly, Allchin (2004) has suggested that studying the history of pseudo-scientific beliefs in the classroom may provide an ideal way to overcome the limitations of textbook science history, which often presents a romanticized, oversimplified, Whigish and distorted view of science (what Allchin refers to as 'pseudohistory').

Educational philosophers have long advocated an instructional approach that proceeds from the student's existing knowledge base (e.g., Dewey 1910/1991). Because many students are likely to embrace pseudo-scientific perspectives, many of which were also embraced by scientists and natural philosophers (of course these views as entertained by the latter most certainly stem from different reasons, experiences, insights and intuitions compared to the former), it is quite appropriate to address these issues and then demonstrate how these ideas developed, withered or were weeded over time. However, the way this development (or withering and weeding) is framed is critically important for the teacher and student. How the pseudo-scientific beliefs will be addressed—as 'silly' and 'fanciful' ideas or hurdles that were triumphantly overcome or as potentially significant generative and creative elements leading to the existing fund of knowledge in a dynamic way—is pedagogically very important in a number of ways. Teaching science and the current scientific knowledge that exists as a creative, open-ended, messy, fuzzy, real world problem solving process not only models this process for the student, but gives the student a more human and cognitively based view of the scientists and portrays her or him in a manner that is similar to the philosopher, historian, artist and similar creative knowledge workers. Teaching and approaching science in this manner would be similar to the way in which Polya advocated the teaching and doing of mathematics (see Carifio & Allen 2005). Shouldn't the explicit message to a young developing student (and potential scientist) be that scientists often have to advance and endure 'seriously flawed' views—which fail at some point in time to conform to established scientific standards and norms—in order to progress. Indeed, this tension was the lifeblood of Kuhn's view of progress in science, which he referred to as the 'essential tension' (Kuhn 1996, p. 79). Based on his extensive historical examination of the physical sciences, Kuhn states: 'Like artists, creative scientists must occasionally be able to live in a world out of joint…' (Kuhn 1996, p. 79). Would this be a better message and one more akin to the early work of Copernicus, Edison, Goodyear, Jenner and Semmelweis?

For instance, the idea that hand washing could prevent infection was thought to be highly speculative, unscientific, 'crazy' and simply wrong by the established medical community, partly because it implicated physicians as the cause of death for countless patients—an unacceptable view by most practitioners and the society and culture they practiced in (Nuland 2003) that today is referred to as resistance to change due to '*stereotype threat*', or one's image of one's self (Steele 1997). However, over time and owing to developments in other areas of medicine and science (such as pathology), this view would become (and still is) a dogmatic principle in science and society. Most students are never exposed or introduced to the context, tensions and factors that led to this 'transition in commitment' (as best as they can be ascertained) in a meaningful way, despite the fact that these transitions were largely mediated by social and cognitive factors and forces. Many students are not more than trivially exposed to this view of the extreme struggles, difficulties, pitfalls and defeats as well as occasional victories involved the creation and development of knowledge, which is something very important to do for current and future knowledge workers who are now not the few but the many in most societies and the world economy. This approach is teaching the 'process of science' as the 'intellectual, emotional, and social struggle' rather than as merely (technical) laboratory operations, which is a very different view of a 'process orientation' in science than the current view. Of course there needs to be a middle ground in science education, one that addresses the context of discovery and the context of justification, but in a way that does not represent the two contexts and their associated epistemological standards as mutually exclusive or unrelated. As we suggested above, science relies on both the generative and fuzzy context of discovery and the weeding function and logical constraints provided by the context of justification. Science educators have traditionally focused on the latter as there are no formal models that demonstrate the amalgamation of these two contexts and their interdependence on one another. The concept map Figure 1 provides a basic overview of the conceptual structure for this work.

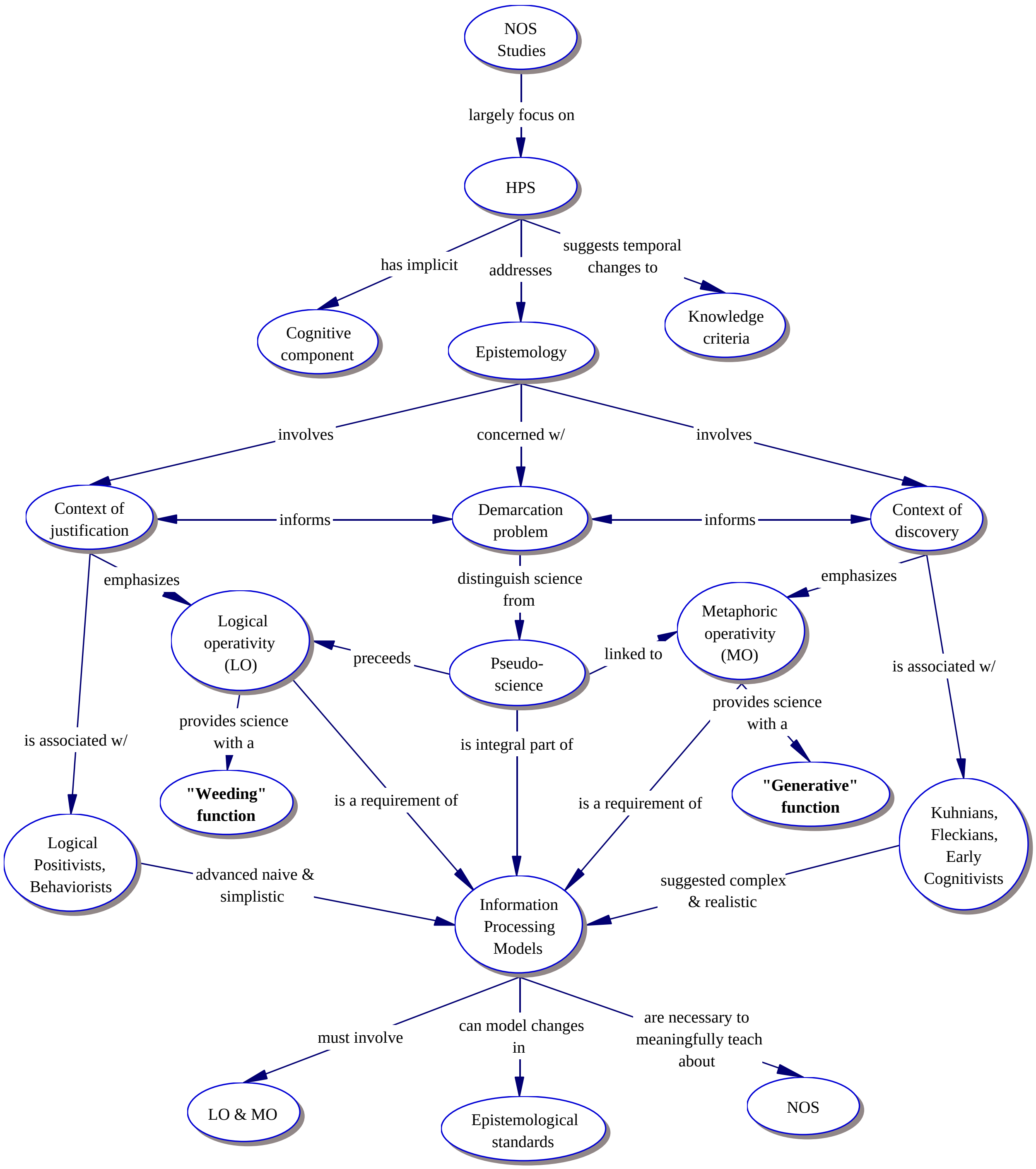

Figure 1. Concept map for this work.

Purpose

The purpose of this paper, therefore, is to provide an initial attempt to model the process by which a pseudo-scientific commitment (by today's standards) evolved into and contributed to a truly scientific commitment, and to demonstrate how changes in epistemological standards were necessary for this transition to occur. Specifically, this paper will document the development of the concept of syphilology from the mystical to the pathological to the purely etiological described by Fleck (1935/1976) in his now classic book *Genesis and Development of a Scientific Fact* from a cognitive perspective. Fleck's work was selected because it anticipates a number of important concepts in cognitive psychology and the cognitive sciences, and because it represents an extremely thorough case study in science. This paper will focus on one of these important cognitive concepts, the *executive controller*, and attempt to model Fleck's account of scientific progress, development and change using this critically important feature of the contemporary information processing system. However, because the executive controller is situated within the information processing system, a brief description of this system is provided to help the reader appreciate the responsibility and regulatory function of the executive.

Methodology

The method used here is primarily an analogical mapping where key features of Carifio's (1993) Integrated Information Processing Model of Learning (described in detail below) are mapped to Fleck's historical descriptions of transitional stages in the development of a mature science, with a particular emphasis on the role and function of the executive controller. Each era described by Fleck and its associated epistemological standards will be described in detail and then linked to competing epistemological standards. The amalgamation of these different standards is graphically represented and offers a model that can describe how pseudo-scientific and scientific ideas initially combine leading to a 'weeding out' process that makes the influence of the former difficult to detect from our 'modern' vantage point. This method is a refinement of Fleck's historiographic method in that it provides actual models that can be manipulated and re-instantiated using different data sets or perhaps different theoretical referents. As with our previous work in this area (see Perla & Carifio 2003, 2004), which is focused on developing dynamic models of scientific knowledge and change, this model allows students and teachers to visualize, actively model and reflect on competing views in science and some of the factors (e.g., intellectual, social, cultural) that potentially influence the decision to reject or embrace a particular commitment at specific points in time.

A Cognitive Model of Information Processing

This paper uses an integrated but primarily cognitive model of information processing developed by Carifio (1993) in order to conceptually organize and translate Fleck's views of how scientific knowledge changes and develops over time, with a particular emphasis on the executive controller. This section briefly introduces and describes Carifio's information processing (cognitive) model and its key features (see Figure 2). A critical underlying feature of this model is the idea that '*all cognitive components are severely limited and that limitations are transcended by conceptualization , abstraction, thinking, elaboration (and fantasy) and ongoing dynamic fuzzy constructions*' (Carifio 1993, p. 4, emphasis added) which are often labeled emotions. These strategies are used to reduce the cognitive load so that information can be processed efficiently in 'real-time' by the extremely limited physical hardware of the model (i.e., the human brain and its distributed neuronal and memory systems). It is also worth noting that cognitive psychology is primarily concerned with understanding behavior, especially behaviors that have the greatest survival value in a complex, rapidly and constantly changing environment. Thus, although Carifio's model is introduced in the context of an individual act of information processing and learning for demonstration purposes, its features are easily extended and applicable to groups of individuals and their *behaviors*.

Another key feature of Carifio's model is that it contends that any given person is *only partially knowledgeable* about anything and most things (almost always) and that everyone is only *partially rational intermittently* (and most of the time); namely, we are only philosophers and philosophical or scientists and scientific occasionally, and not continuously and all of the time and on all things (at least those of us who are truthful about these things). There are, however, *degrees* of partiality (of knowledge and rationality) and the *frequency* and *length* of these intermittent periods and activities. Carifio's view, like Selfridge's (1959) and Freud's (1959) is that we are all intermittently irrational, illogical, 'non-cognitive', and emotional, and computers will be too when they advance to the state of human complexity and need to make new understandings in a chaotic and constantly change world and universe where one has to think emotions and feel ideas (have a fundamental core unity) to remain a part of the unfolding flow. Carifio's model includes the unconscious, emotions, personality, social identity and relationships with others (family, community, and culture) and is a model where the processor is capable of 'thinking emotions' and 'feeling ideas' as these processes and phenomena are only fuzzily separated at best and a 'foam' with different 'beta-weights' in different contexts, processes and situations. Thus in Carifio's model the 'pure act of philosophy' (or science) is possible (by someone who is highly knowledgeable in one or more domains, quintessentially logical and rationale and culture free and completely altruistic for a long and sustained period of time) as well as the pure act of 'madness or pseudo or fantastic philosophy or science or human action' and all points in between these two extremes which tend to be different places for students, the lay public and professional philosophers and scientists (hopefully). As the Nobel laureate and highly creative physicist Murray Gell-Mann has stated about what he calls the soft sciences:

> I have personally always been astonished by the tendency of so many academic psychologists, economists and even anthropologists to treat human beings as entirely rational or nearly so. Assuming that human beings are rational oftenmakes it easier to construct a theory of how they act, but such a theory is often not very realistic. (Gell-Mann as cited in Matthews 1994, p. 4)

Carifio's model holds the same view, but also holds it for scientists and philosophers as well. Figure 2 presents Carifio's model in systems form with the executive controller highlighted. Table I lists the five basic principles and sub-components of this model.

Schemata

The idea of a schema (pl. schemata) is central to Carifio's model of information processing (and indeed to the cognitive sciences) and needs to be understood to appreciate the model. A schema is a dynamic representation and knowledge structure in memory related to a particular context that is not necessarily reflective of the 'real world'. Despite the fact that there are a number of different types of schemata (e.g., cognitive, metacognitive, procedural, and affective), the fundamental units of all schemata are concepts and principles. Further, unlike other theorists in this area, Carifio contends that there are different kinds and types of schema in any given domain which range from the simple tree-structure schemata that one sees in the artificial intelligence and computer science literature and the simple tree-structure concept maps one sees in the psychological and educational literature, the simple tree-structure being the only form posed in these literatures in both theory and example, to very complex integrated higher order structures and organizations of inter-related concepts and principles (or factors) similar to the higher order multi-factor generalized mathematical forms seen in Rene Thom's (1972/1989) non-linear catastrophe

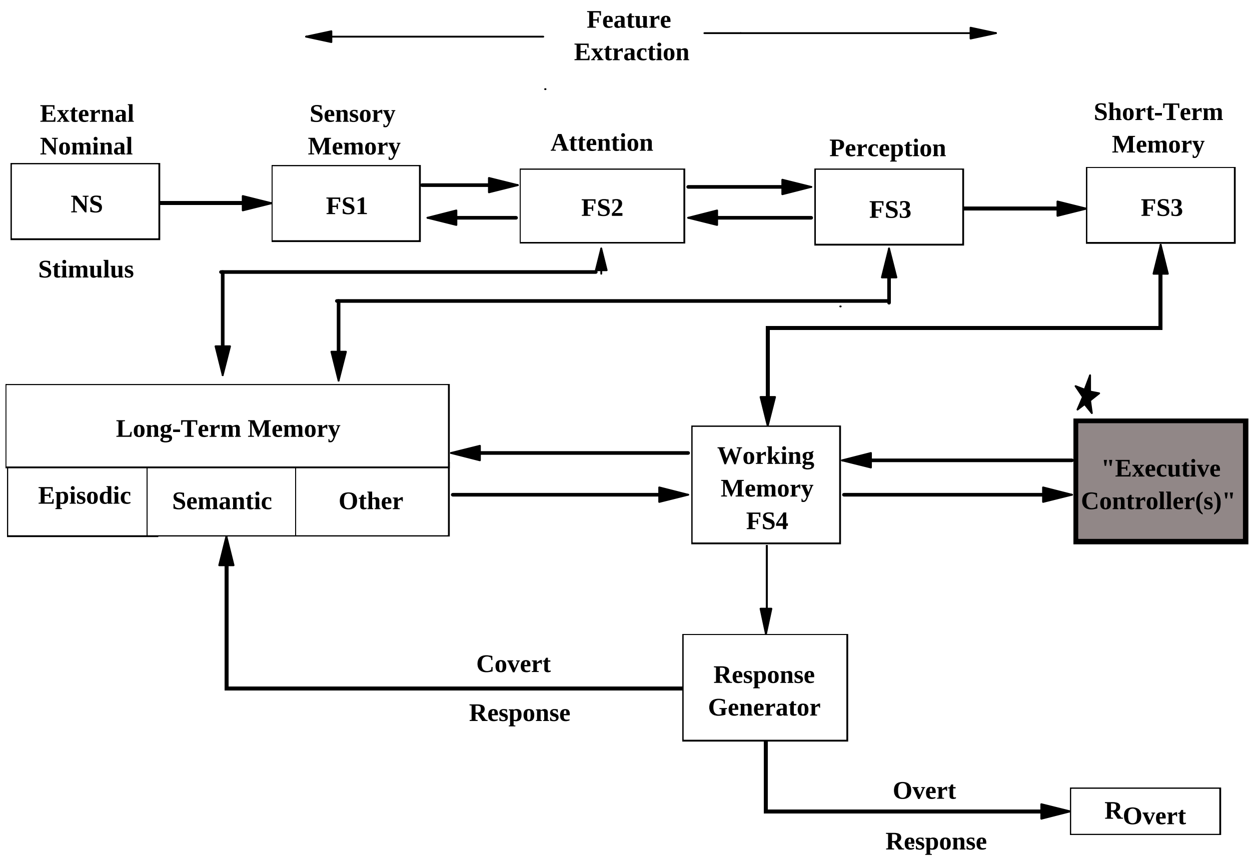

Figure 2. Information-Processing View of 'Cognition' and 'Cognitive Processing' (after Carifio, 1993)

theory. These higher order, more complex, non-linear, non-hierarchical schema, tend to be the form and structure of scientific schema and higher order knowledge, particularly the ones that are ‘theory-based’ or ‘theory-representing’. Such schemata are much more difficult to learn, understand and use in thinking for novices than simple tree-structure schema, and this is one reason why scientific knowledge beyond the simple and elementary level is often much harder to learn and understand. This particular point, however, is beyond the scope of the current work, but the non-linear model of local (assimilatory) and global (accommodative) scientific change is an example of such a higher-order and (causally) integrated schema.

Schemata, whatever their type and/or structure, are highly conservative as their principle function is to organize and reduce information. In fact, if schemata were too large or too complex they would not be able produce appropriate timely responses (and this has significant evolutionary implications as being able to predict and respond to the external environment is a matter of survival). Schemata are guided by normative rules and exception rules, which mean that schemata have ‘fuzzy’ boundaries and are not linear and immutable, but are flexible and dynamic (see Barlett 1932) and are loosely or tightly structured fuzzy subsets (Zadeh 1965) with core generative elements. Indeed, each schema is (theoretically) associated with a probability value, which is influenced by particular epistemological standards (and these standards are influenced largely by developmental level). ‘Procedural’ and ‘metacognitive’ schemata are often described as ‘scripts’, ‘frames’ or sequences of actions that follow general patterns and parallel processes (Minsky, 1986), and are ideally suited to fill in or replace information as necessary as schemata have

Table I. Five Basic Principles and Sub-Components of Carifio's (1993) Integrative Information Processing Model and Theory of Learning

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1. Cognitive Limits:

- All cognitive components and systems are *severely limited*.
- These limitations are transcended by conceptualization , abstraction, thinking, elaboration (and fantasy) and ongoing dynamic fuzzy constructions which are often labeled emotions.

2. Partial Rationality:

- Any given person is only *partially knowledgeable* about anything and most things (almost always).
- Everyone is only *partially rational* intermittently (and most of the time); namely, we are only philosophers and philosophical or scientists and scientific occasionally, and not continuously and all of the time and on all things.
- There are, however, *degrees of partiality* (of knowledge and rationality) and the frequency and length of these intermittent periods and activities.

3. Schemata:

- A schema is a dynamic representation and knowledge structure in memory related to a particular context that is not necessarily reflective of the "real world."
- Despite the fact that there are a number of different types of schemata (e.g., cognitive, metacognitive, procedural, and affective), the fundamental units of all schemata are concepts and principles.
- There are *different kinds and types of schema* in any given domain, which range from the simple tree-structure schemata to very complex integrated higher order structures and organizations of inter-related concepts and principles (or factors).

4. Parallel Processing:

- There is not a "single" process or "processing" at any given moment in a processing system, but rather a *multiplicity of different processes and processings* going on that are loosely and fuzzily coordinated and interconnected with many tests, checks and balances, information exchanges, error corrections and redundancies very similar to Selfridge's (1959) original Pandemonium Model of cognitive processes and organizations.

5. Executive Families:

- There is not one executive processor, or central processing unit or type of central processing unit, which is the view of the classic model and the preponderance of theories in this area, but rather a *family of (qualitatively different) executive processors* which are loosely coupled and work in parallel and communicate with each other through fuzzy channels somewhat like the two hemispheres of the brain and the corpus collosum.
- Each of these executive processors in a person's family of executive processors is a *generative specialized compiler with its own representational system, language, logic and set of functions and commands which goes through development level and customization* (Cattell's [1963] crystallization) over time through interactions with the outer and inner environment.
- Additionally, there is or tends to be a '*dominance hierarchy*' among the executive controllers in the family relative to primary or major control of the overall processing at any given time and in any given context as well as the order in which executive processors are invoked (i.e., there is a dominant and latent factor and processing).

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episodic (procedural) and semantic (declarative) instantiated forms and components. All schemata (beyond the very initial state) have an 'inner core (of explanatory elements)' and a 'peripheral or auxiliary belt' similar to what Lakatos (1970) has posed for scientific theory and knowledge. This particular and highly important characteristic of schemata is not explicit in most theories except Carifio's. In terms of academic knowledge and academic learning, it is a very important characteristic as well as for pseudo and fantastic science as 'inner core (of explanatory elements)' is usually radically different from the current scientific theory version of the phenomenon in question. All schemas generate and/or contain specific rules of covert and overt behaviors and specific psychological norms both explicitly and implicitly, and all schemata are to some degree 'constructed' and 'socially mediated' and 'social' entities between schema holders and the (fuzzy) communities they form. Schemata that are developed through automatic and unconscious learning processes (i.e., classical conditioning or latent and implicit observational learning) are less 'constructed and socially mediated' than cognitive or meta-cognitive (more conscious and 'plastic') schemata. These 'constructed' and 'socially mediated' aspects of schemata have narrow to wide individual and collective variability (i.e., are 'fuzzy and loose'), otherwise there would not be 'madness' or (extreme) creativity and 'paradigm shifts'

Schemata develop from external and internal data or experience through a process of inference (induction) and confirmation (deduction) that could be characterized as a process of cognitive confirmation, particularly if external and internal verification processes are used. The perception of data leads to inferences that lead to the formation of generalizations or (LISP like) representations known as schemata. Once formed, the viability of a particular schema is subject to confirmatory activities that map the schema back to the data, a process known as confirmation or top down processing. This cycle of inference and confirmation has a normalizing (reducing and constraining or weeding) effect on thinking. Schemata generally change in one of two ways. The first way schemata can change is through assimilation (local small-scale changes). This is a situation where information is either added to or deleted from an existing schema. In other words, assimilation can be progressive or degenerative, but always leaves the core of the schema functional and unchanged. For example, Ausubel's (1968) notion of obliterative subsumption is an excellent example of assimilation. Briefly stated, obliterative subsumption states the more you learn and form generalizations, the less you need details and will 'throw them away', or simply lose access to them. The second, less frequent way a schema can change is through a process known as accommodation (or global change), a process that leads to the complete restructuring to the core features of an existing schema (which is posit to happen all at once in the older views of accommodation or large-scale schema change, which have focused on only very young children who at best have simple proto-schemas).

In reality, completely restructuring a very large and complex relational data-base (which is very similar to a mature schema, model, theory or paradigm) is not done and does not happen all at once, nor is it ever 100% complete and without errors as any large-scale and usually very bald database programmer will tell you. In reality, as previously stated, scientific theories or paradigms are far more complex and detailed than the overly simple stimuli in Gestalt experiments and examples or childhood proto-schemas, and the process of Gestalt switching for real complex concepts, views, theories and paradigm is rarely 'all at once or not at all', but rather is a chaotic and often unpredictable series of steps with seven league boots to the last 'Ah-ha' step, which requires a far greater number of steps for a mature scientist who has build up very complex knowledge structures than a young student or general lay person. Achieving schema accommodations is just not that easy and is usually a process rift with difficulties and cognitive dissonance and often much emotion and negative feeling particularly in high school and undergraduate students which makes teaching for schema accommodation very difficult in today's climate and is one of the reasons a great deal of science education today is focused merely on knowledge assimilation. However, these factors are the very reasons why teaching science as the type of human and creative process we have outlined here beginning at an early age is so important as it will both build meta-cognitive skills and attitudes at being open to accommodating new ideas, models, theories and paradigms and begin the process of weeding and changing pseudo-scientific and fantastic science views and beliefs much earlier and before they are deeply and often unconsciously ingrained in students schemas and schemata which are of critical importance. In short, schemata directly or indirectly influence every aspect of the information-processing model in Figure 2, which is briefly described below.

Parallel Processing

One of the most important aspects of Carifio's information processing model are the bi-directional arrows, which demonstrate the feature of *parallel processing*, which involves any mental processing where more than one operation occurs simultaneously (Ashcraft 2002). Parallel processing contradicts the early behaviorist view of thinking and memory and it represents a significant advance and extension to the 'standard' and sequential information processing models developed during the 1960's (Atkinson & Shiffrin 1968) and updated versions of these sequential and 'single central processing unit' view of computers and human information processing (e.g., Anderson 1996, and in others). Parallel processing (so convincingly shown by MRI's and CAT scans let alone sixth generation computers), therefore, ushered in a more complex, dynamic and sophisticated view of cognition than had previously been acknowledged. There is not a 'single' process or 'processing' at any given moment in time go in a parallel processing system, but rather a multiplicity of different processes and processings going on that are loosely and fuzzily coordinated and interconnected with many tests, checks and balances, information exchanges, error corrections and redundancies very similar to Selfridge's (1959) original Pandemonium Model of cognitive processes and organizations. The subject of parallel processing systems requires a paper all of its own but with these basic points in mind we may return attention to Carifio's model.

Basic Components of the Processing System

The front end of Carifio's model is focused on *feature extraction* and is responsible for the initial processing of the *nominal* (external) *stimulus* (Sn). *Sensory memory* transforms the information (electrical, mechanical, magnetic energies) in the nominal stimulus into neural impulses, which are then transmitted to the brain for further processing. Sensory memory is fleeting and only captures a small subset of the information related to the nominal stimulus. The information brought into sensory memory is referred to as the *functional* (internal) *stimulus* (Sf1), which is modified during each stage of the process. It should be clearly noted that sensory memory is *one* source of informational input into working memory, the other sources being *long term memories of various kinds*, perception, inference, deduction, analogical and metaphoric reasoning and thinking, which are features and functions that reside in some developed form in the executive controller. Hume and Locke were out and outright wrong about 'all sensations' existing in the senses. All ('primary') sensations and information are not 'in the senses' and this is a two century old category mistake (Ryle 1949) that has been the lynch pin foundation of behaviorism and the logical positivist model of cognitive processes and functioning. *Attention* focuses on a subset (Sf2) of the key features extracted from sensory memory or other input channels. Attention is driven by existing knowledge structures and representations in long-term memory (i.e., schemata) and is highly selective and divided into *focal* (main) attention and *peripheral* (minor but might be important or important later) attention (which is akin in many situations to simultaneously having a theory generated and rival hypothesis or hedging one's bets). Consequently, schemata influence what an individual attends to (and makes major or minor) and what is ignored.

Perception is a dynamic and active process that involves the encoding (interpretation, expansion and elaboration) of the functional stimulus (Sf2) from information derived from schemata in long-term memory. This encoding leads to further changes in the functional stimulus (Sf3), which are temporarily stored in *short-term memory*. Some of the encoded information in short-term memory will be moved to *working memory* where it is further processed and analyzed using information derived from *episodic* and *semantic long-term memory* (usually, but there is a 'bubble memory' emergency over-ride) as well as from the 'strategies' and 'programs' of the *executive controller*, which results in further changes to the functional stimulus (Sf4). Episodic (or procedural) long-term memory stores personal, autobiographical, experienced memories such as the names of family members. Information is stored in narrative or story-based schemata or 'scripts' that are chronologically organized, semi-logical and concrete. Semantic (or abstract) long-term memory, on the other hand, represents the long-term storage of your general world knowledge including different concepts and their relations. The schemata of semantic long-term memory specialize in storing abstract concepts that are organized in structured conceptual networks. In 'experts' these networks are hierarchically organized and tend to be highly developed and logically constrained. Information stored in 'bubble memory', it should be noted, cannot be (well) integrated into these other (well organized) long term memory stores and thus it tends to be 'traumatic' information and experiences which can be cued or triggered by an automatic emergency over-ride function (most probably located in the reticulate activating structure at the base of the brain).

The model and theory outlined above, particularly when the executive controller outlined below is incorporated into it, gives a 'sixth generation AI type' model that can explain and handle 'sanity' and 'madness' and states in between and even *oscillating states***,** as well as science and pseudo-science and their associated beliefs and etiologies as well as science and fantastic science.

We think that it is important to see and understand that all of the fantastic science that is around currently in large amounts *is collateral damage to the massive amounts of the good science that has been done this century* and the number of good scientists, charlatans and quacks working in all scientific areas now as opposed to other times. The better the science gets and the more rapidly it discovers new knowledge, and particularly theory or paradigm shifting knowledge, the more pseudo-science and fantastic science there is going to be, such as fake baseball cards and paintings etc. This is because of the climate and *the shallow beliefs and epistemological standards of the gullible and the money involved*, which make teaching science, as outlined here, and teaching students the skills to sort out these things increasingly more important and at the mass level. This approach to teaching will become more important in the coming decades as we think that discovery is still ramping up and not ramping down. And the key to understand these several important points is the executive controller.

The Executive Controller

The executive controller is typically and classically defined in information processing and cognitive models as the component that oversees and controls all processing and processing activities (Ashcraft 2002). This 'processing' and these 'processing activities' range from what are often called routine physical 'house keeping' functions and tasks like the operating system on a computer or what the autonomic nervous systems does in the body (i.e., lower order firmware) to the 'intelligence' and '(logical) reasoning and thinking' functions (i.e., 'higher order firm to software') that perform 'mental operations (of various kinds)' on the information being processed (Carter 1998) to planning, strategizing, evaluating, and decision-making functions, as well as epistemological standards (Zeman 2002). The problem with this classical definition is that it is an extremely limited view and representation of the executive controller that is rooted in pre-Lashley neurology, second generational computing, and first generation artificial intelligence, as well as first generation cognitive psychology (Carifio 1993).

The first problem with this classical view of the executive processor is that it does not include *metacognition*, which it absolutely must and for which the neurological physiology has most recently begun to be uncovered in the incredibly remarkable function of the glial cells in the brain, which previously were thought to be just structural support cells for neurons (Fields 2004), which illustrates several of the central points of this work. Glial cells monitor and evaluate what is occurring with neural circuits and communicate this information to other gial cells that are monitoring other circuits both contiguously and remotely. Glial cells develop and communicate information about information, which is the very definition of metacognition. The work of Krebs, Huttmann and Stienhauser (2004) has also suggested that the products of the glial cells influence, regulate, and coordinate information in a given neural network thereby influencing the pace and quality of learning and memory formation. All of these findings, which are becoming more numerous everyday, offer strong support for metacognitive functioning at the cellular level and thus inform modern integrative information processing models such as the model outlined here at a deeper more fundamental and biological level.

The next problem with this classical view is that it both assumes and asserts that there is *only one kind of intelligence* and *only one kind of logic* and *only one type of operativity* and *only one kind or mode of reasoning and thinking* similar to the views thirty years ago that there was *only one kind of memory and memory process* (see Schatner 1996, 1999). None of these aforementioned views and positions are correct, nor are they true of modern sixth generation computers or 'AI' models let alone human beings and the human brain. There are several types of 'intelligence' (see Guilford 1967 and Gardner 1993), several 'logics' (see Wienerberger 2004) and at least two types of operativity (*logical* and *metaphoric*) and associated modes of 'reasoning and thinking' (i.e., the brain is always multi-tasking at all levels), which illustrate a number of central points.

First, there *is not one executive processor, or central processing unit or type of central processing unit*, which is the view of the classic model and the preponderance of theories in this area, but rather *a family of (qualitatively different) executive processors* which are *loosely coupled* and *work in parallel* and communicate with each other through fuzzy channels somewhat like the two hemispheres of the brain and the corpus collosum. Further, each of these executive processors has *a given development level or state at any given point in time* (similar to Piaget's levels of logical development and thinking)**,** and the developmental level or state of any given executive processor does not have to be the same as other executive processors in the family (i.e., development is local and not global and uniform). Additionally, there is or tends to be a *'dominance hierarchy'* among the executive controllers in the family relative to primary or major control of the overall processing at any given time and in any given context as well as the order in which executive processors are invoked (i.e., there is a dominant and latent factor and processing). At both the macro and micro levels, compilers and schemas tend to be hierarchically organized, as one becomes more developed and 'an adult', which is a major reason why 'bottoms-up' processing (as opposed to 'top-down' processing) often is so difficult and problematic.

The executive controller is the most underdeveloped component of most information processing and cognitive models currently as most work initially focused on the other components (i.e., attention, memory, perception) and logical thinking was the initial focus of artificial intelligence and education. There are good reasons for this state of affairs as a comprehensive theory of the executive processor(s) is an extremely difficult problem (and beyond the scope of this work), and an area where angels fear to tread. But tread we all must, as it is the heart and soul of the questions, model, and human information processing (Crick 1994). The success of the 'cognitive revolution' (which ironically has increasingly become more and more of a metaphor) encouraged its expansion into and inclusion of other areas including alternative intelligences and alternative logics and affect, emotions, values, ethics and personality. All of these elements must 'reside someplace' and 'reside someplace within the model' to some degree more or less. The model of a family of executive processors and a multi-tasking parallel processing executive can both handle and integrate all of these 'screaming demon' processes and transformational processing components (Selfridge 1959) in the model. Further, in this model and view 'control' is 'shared' between the executive processors or controllers.

The way to think about and model each of these executive processors in a person's family of executive processors is that each one is a *generative specialized compiler with its own representational system, language, logic and set of functions and commands which goes through development level and customization (Cattell's [1963] crystallization) over time through interactions with the outer and inner environment.* Compilers are very large, intricate and specialized software programs on computers that translate, elaborate and transform higher order communications and representations (i.e., information) flowing through the computer into forms that can be processed by the machine's hardware (neurology) and then translate, elaborate and transform the hardware (neurological) results and products back into the higher order presentations and communications. These translations and transformations are called *compilation processes***,** and computers can do very little (and not very quickly) without the appropriate compiler. Further, every complier has it own *'semantic (meaning system and network)'* and processes *propositional statements* and constructs propositional statements as input to and out from machine level processing. These (tentative) empirical facts, and logical facts (as we have not in over 50 years been able to construct a computer that functions in another manner), are why *propositional representation* (and processing) *in the wide variety of forms it may take* is the absolute core and fundamental concept and construct of *what learning is* and *what is stored* in this view, and not the association or connection in the many and varied forms that it persists in all of this literature in the last hundred years (Dunnett 1991; Neisser 1967; Norman 1981; and Pinker 1999). It is also the reason why both memory and processing is dynamic and constructive (Schacter & Scarry 2000) and not static and inert and computationally algorithmic (Culler & Mulder 2004). Associations and connections are 'pigeon (and non-meaningful) propositions' and, as Lashley (1950) said to neurologist and others, meaningful and comprehensive theories of neither neurology nor learning can be built with the association or (content-less) connection as the core theoretical concept. And there is another critically important point about compilers.

A given compiler may be a *primitive, sophisticated, or highly advanced* (and expert) version of the specialized compiler in question, and if the machine has 'self-correcting code' or 'genetic' (re)programming (i.e., metacognitive) capabilities, a given specialized compiler may 'rewrite' and transform itself to the next level as a result of interacting with the outer or inner environment. Piaget's levels of development of logical thinking with the various limitations and abilities of each level (Piaget & Inhelder1969) would be an exemplar of a specialized compiler and the points made here about specialized compilers. Further, it is now known that a person's level of Piagetian logical development is not uniform across all (academic) content areas, which is a fact that can be explained by Carifio's model and one that is perfectly consistent with it and the view it proposes. Given these last points, there could also be individual differences between the same generative specialized compilers (e.g., logical development level) running on two different 'machines' and interacting with two somewhat dissimilar outer and inner environments. So this view can account for both *subjectivity* and *individual differences* without difficulties. Writing a compiler, even a primitive one, is one of the hardest of programming tasks, and compilers and various versions of a compiler can also have a variety of bugs and errors or *limitations* at any given point in time which impact both their functioning and the products they make, which can account for a wide variety of external and internal behaviors observed. As any computer chosen at random these days anywhere will most likely have 8 to 10 different compilers that can be evoked or called into usage either as a primary or background processing task, it is not in anyway untoward to represent the executive process as a family of compilers which is not pseudo, proto or fantastic science and fairly well supported by the highly differentiated models of the brain we currently have with its many varieties of specialized processing centers operating in parallel. Further, compilers may be active and encoding and processing simultaneously, which means that all information flowing through the processor is *multiply encoded* to some degree (but stored in different 'work files' or memories temporarily and permanently) and made focal or peripheral (but present), and such a design and manner of processing is called *division of labor* which *speeds up* processing and product construction. Single view or 'fixed frame' models of information processing tend to call the activities and actions of other compilers 'intrusions' into their view (somewhat like dark matter and dark energy in the universe), or exogenous or 'nuisance' variables that are creating 'noise' and 'errors' in processing. They are nuisances to the single fix frame view but the information is usually much more than noise or errors. There is, however, one last very important point about the 'executive controller'.

There is no reason to believe or strong evidence to support that the executive control is 'dysfunctional' or 'incapacitated' when one is 'asleep' (Carifio 1993). Such a view is an archaic value judgment, misconception, and fear of 'darkness' (and several of its associated problems) as opposed to logos (consciousness and logic) and the light. The history of science and scientific discoveries and breakthroughs has numerous major and minor examples of scientists who 'slept' (literally or figurative) 'perchance to dream'. All modern work on and theories of 'consciousness' (as well as sleep) see 'sleep' as another and qualitatively different state of consciousness (what one could call 'dark matter') as well as another and qualitatively different mode of information processing (what one could call 'dark energy'). This alternative and qualitatively different mode of information processing is dreaming, imagination, visualizing, fantasy, divergent thinking, creativity, delusions and hallucination. Both consciousness and logic, it should be clearly noted, have their own similar problems (and thorns) in both false memories and false inferences and deductions. 'Sleep' is essentially when the 'constraints' of logic, current (conscious) rules and representation of reality and the constant and unrelenting stream of external information (which is often an absolutely overwhelming torrent in the modern world as well as one's profession) are temporarily loosened (if not suspended), and other 'logics' and other 'operativities' and other rules and representation of reality and internal information begin to function in a both a phase and sea change of the executive processor.

'Sleep' is 'dangerous and risky' in all of the many subtle meanings of this phrase, and all sleep research show that the brain is anything but 'asleep' during these periods. As Crick (1994) has pointed out and discussed in detail in *The Astonishing Hypothesis*, the outstanding question is why we sleep and why has it been selectively retained (including what is called 'micro sleep') for millions of years. The simplest answer comes from Godel's Undecidability and Incompleteness theorems and the basic theorems (and facts) of modern cognitive psychology. All representational systems, 'logics' and operativities are severely limited with their own sets of strengths and weaknesses (like each of the 5 basic senses), and one needs to multiply represent and multiply process intricate informational complexes and transmissions from different perspectives and with different operativities (in parallel) to capitalize on the strengths and transcend the limitations of each to converge probabilistically on better and better representation of the selectively retained tentatives we call 'knowledge' and 'knowing'. All mature and 'adult' cognition is 'interdisciplinary' as are all 'solid' cognitions and representations as Godel kept showing us over and over again in different ways. Metaphoric operativity is needed, and needs to be developed and cultivated, as much as logical operativity to have mature and adult operativity and cognitions.

To utilize or to be locked into and exclusively (or almost exclusively) dominated by one or the other, or functionally fixated and not able to switch from one to the other, is a primary cause of most of the problems and difficulties pointed out and discussed in this paper relative to science, pseudo-science and fantastic science as well as the processes by which proto-science (often seen as pseudo-science) comes about and develops into science or fantastic science. The key features, characteristics, and developmental state of the information processor's executive control is one of the critical (if not most critical) 'covert variables' that determines whether the view or claim espoused or assented to is pseudo-science, proto-science, science or fantastic science and whether the adaptation and development of the view will be progressive, sterile, stuck (and ideological), transformed or weeded.

Freud (1899/1999) charted the royal road to the unconscious (dark matter) and the processes and dynamics of metaphoric operativity (dark energy) in his seminal work on dream analysis, creativity, and studies of genius including scientific genius. Many philosophers, poets, writers and artists have contributed to these charts both before and after Freud and he drew a great deal from their work in developing his model of the conscious and unconscious information processing systems and the relationship and interactions between the two. Both Freud and many of his views have recently undergone strong rehabilitation and particularly in the scientific and cognitive science arenas (see Horgan 1996 and Solms 2004 for details). There is a long line of work in both the philosophy and nature science, scientific knowledge and scientific change (for example, see Hanson 1958 and Feyerabend 1981) as well as cognition, thinking and problem solving (for example see Carifio 1976) that has drawn upon many of Freud's ideas, views and theories, both overtly but most often covertly, because of the times, temperament, and allegiances, so that many of our views and points outlined here are not that radical or new, but rather new and improved versions, statements, and re-introductions of older proto-science and perspectives thus re-establishing a broader interdisciplinary view and understanding.

Response Generator

Finally, the response generator is the feature of the system that translates the information in working memory into 'appropriate' *overt* and *covert responses*. Changes to schemata in long-term memory are characterized as *covert responding* and may represent assimilation (expansion and elaboration) or accommodation (conceptual reorganization). In other words, schemata can change in at least two qualitatively different ways, which may be also characterized as 'local, small and at the periphery' (assimilation) or 'global, large and in the core' (accommodation) changes.

Parenthetically, it is interesting to note that the criticism levied against Kuhn for the multiple uses of the term paradigm (see Masteman 1970) could also be made against Fleck's use of the terms thought collectives and thought styles (described below). However, these concerns and issues are vitiated in the context of cognitive psychology and schema theory, as Masterman's differentiation and elaboration of Kuhn's concept of a paradigm suggests. Indeed, Masterman's work clearly demonstrates that paradigms (and perhaps Fleck's thought collectives also) involve multiple representations, concepts, functions and organizing principles for their users (i.e., scientists or groups of scientists). This type of multifaceted, dynamic, differentiated and fuzzy representational system is exactly what defines schemata and schema theory. To criticize Kuhn and Fleck (or anyone attempting a synthesis of scientific progress, development and change) for not exercising exact precision and coherence at the general (macro) level is to adopt a rather naïve, unrealistic and static view of the scientific enterprise, paradigms and cognitive schemata which embody these entities[2]. This point and criticism is where the philosophy of science must give way to cognitive psychology and cognitive theories and models. As is demonstrated below, these multiple but highly correlated uses and representations, which converge at a normative representation (as well as definitions and meanings) is a guiding principle of Fleck's overall thesis.

One last concept is needed to simplify the discussion of thought collectives, thought styles, comparative epistemologies and psuedo, fantastic, proto and currently accepted science below, and that concept is *the span of control* (consciousness) of the person processing information. The span of control refers to the preferences and executable options in memory and capabilities of a person's executive processor that allow the person to use a specific approach to solve a problem, which are developmentally mediated and also influenced by the social and cultural milieu. It is a higher order version and corollary of Miller's (1956) 7 +/- 2 limitation (parameter) for short-term memory and a concept that is widely used in business and management theory. For example, a child at the concrete level of operations, an 18th century physician, a priest during the Renaissance period and a contemporary scientists will all approach the concept of 'disease' using different standards and criteria of meaning-making. The next section of this paper addresses the issue of how epistemological standards change among a group of 'scientists' between the 16th and 18th century (or more appropriately, natural philosophers) from the mystical to the purely empirical and how these changes influence the perception of progress in science. Lastly, Carifio's integrated model of information processing and learning presented here is both a general and highly abstract model and theory and must be instantianated in a particularly context and with particular contents to become 'thick and rich' and 'concrete' with particularized predictions. This point is also a fundamental tenant of his model and theory; namely, specific content, information, meanings and 'content-addressable memory and programs' are part of the very fundamental things that make the human information processor and learner both human and an information processor, and these elements simply cannot be ignored or squeezed out of consideration or theory no matter what level or kind of modeling and theorizing one is doing. Fleck and his work and views are an instantiation of Carifio's model.

Comparative Epistemology, Thought Collectives and Thought Styles

Many of Fleck's key concepts are consistent with fundamental principles in cognitive psychology and the information-processing model described above. Three such related concepts are discussed in this section: (1) comparative epistemology, (2) thought collective and (3) thought style. Since thought collectives and thought styles are described in the context of what Fleck calls "comparative epistemology", a definition of these terms is deferred until the latter is briefly introduced and described.

Fleck was among the fist (including Reichenbach 1938) to make a distinction between the context of *epistemological justification* and the context of *discovery*. Although Fleck certainly acknowledged the import of legitimizing science vis-à-vis rigorous logical and 'objective' standards, he argued (like Kuhn) that this approach was not the only approach or criterion needed to understand scientific progress, nor the most important. Instead, Fleck argued for what he called a 'comparative epistemology', which is 'a rule of thought that allows one to make use of more details and more compulsory connections, as the history of science teaches us' (Fleck 1976, p. 22). Comparative epistemology involves the interaction of three factors: the subject to be known, the knowing (cognizing) subject and the existing stock of knowledge, with an emphasis on the dynamic interaction between the knowing subject and the existing stock of knowledge (the details of which are represented in Carifio's model). Fleck recognized that existing knowledge 'influences the particular method of cognition; and cognition, in turn, enlarges, renews and gives fresh meaning to what is already known' (Fleck 1976, p. 38). Therefore, cognition is not an individual act because the stock of existing knowledge, which is a socially derived product, far exceeds the range of any individual. In other words, the knower interacting with the known *is a partial and socially mediated process* (as characterized in Carifio's model). This idea is remarkably consistent with Vygotsky's (1978) view that the development of knowledge is a social construction. In fact, Fleck argued that 'cognition is the most socially conditioned activity of man, and knowledge is the paramount social creation [*Gebilde*]' (Fleck 1976, p. 42). Fleck also points out that 'cognition modifies the knower so as to adapt him harmoniously to his acquired knowledge' (Fleck 1976, pp. 86-87). This process ensures a level of stability and agreement relative to the knowledge within an established and dominant tradition and is consistent with the normalizing and equilibrating features of schemata. This view explains how scientific disciplines develop into relatively closed and 'stylized' systems of knowledge.

Understanding scientific progress and the growth of knowledge then becomes a matter of understanding how the knower interacts with the body of existing knowledge and how this interaction influences the development of a 'closed and style-permeated system of opinions' (Fleck 1976, p. 38) from the hazy, ill-defined, and most often unjustifiable pre-ideas and proto-schema. Comparative epistemology also looks to understand how conceptions and different pre-ideas are transferred between different thought collectives (defined below). Again, from a cognitive perspective, this conservative-reductionist tendency is termed *normalization* and is a necessary strategy for the severely limited information processing 'hardware' and 'software' of the human cognitive system.

In describing these cognitive processes and tendencies, Fleck introduces two related concepts: *thought collectives* and *thought styles*. A thought collective is defined as 'a community of persons mutually exchanging ideas or maintaining intellectual interaction' (Fleck 1976, p. 39). *Thought collectives* are dynamic and can involve as few as two people engaged in a rigorous exchange of viewpoints that creates an environment where individuals express ideas that they could not express in isolation. Once established, the very nature of the thought collective implies specific 'rules of behavior' and specific psychological norms that are constantly being refined. *Thought styles* are epistemological standards, which bond members of the thought collective from a socio-cultural and historical perspective and determine the specific criteria for concept formation. Thus conceived, thoughts styles dictate the range and admissibility of different methods of inquiry, ideas and viewpoints developed within the collective, and ipso facto provide a historical record for the development of thought along specific lines. Because thought styles are framed in a socio-cultural context, they are not merely the product of a formal logic, but are highly influenced by the social conditions of their time. For this reason, Fleck comments that: 'Sixteenth century physicians were by no means at liberty to replace the mythical-ethical concept of syphilis [which was socially accepted at that time] with one based upon natural science and pathogenesis' (Fleck 1976, p. 9). Acquisition of the pathogenic concept of syphilis would require a change in the thought style of the collective.

From a cognitive perspective, thought styles are analogous to epistemological standards, which the executive controller utilizes in its functioning. To draw an analogy from computer science and in the context of Carifio's model, if the executive controller is the central (family of) processing unit(s) of the cognitive system, then epistemological standards are the executable options (flexible rules) of the software (compilers being used) and their associated beta (dominance) weights. By understanding the general epistemological standards used by an individual or group one can begin to understand (and even fuzzily predict) the output from the response generator. We can also more precisely characterize and diagnose claims of pseudo-science by using a one-to-one mapping of the epistemological standards of normal science to pseudo-science.

On a different level, historians of science and scholars in a wide range of settings have long recognized the role of epistemological standards in their work, in many cases without realizing it. For example, the popular conjecture that it is inappropriate to judge historical claims, arguments, theories and commitments using modern insight and without proper contextualization is to argue that epistemological standards are assumed to be different between the past and present, which therefore leads to an inappropriate or tenuous comparison at best. Recognizing a genuine concern for different epistemological standards facilitates a certain intellectual humility insofar as past ideas are not seen merely as 'right or wrong', but as operating under different epistemic assumptions and rules in different social contexts. Kuhn, arguably the greatest science historian of all time, recalled how this realization relative to Aristotelian physics provided the breakthrough insight needed to develop his main thesis in *The Structure of Scientific Revolutions* and its core concept of a paradigm. Kuhn had learned to read like an Aristotelian physicist, which resolved many of his struggles to understand the viewpoints of that era.

> After I achieved this one [insight], strained metaphors often became naturalistic reports, and much apparent absurdity vanished. I did not become an Aristotelian physicist as a result, but I had to some extent learned to think like one. Thereafter I had few problems understanding why Aristotle had said what he did about motion or why his statements were taken so seriously. I still recognized difficulties in his physics, but they were not blatant and few of them could properly be characterized as mere mistakes. (Kuhn 1977, p. xii).

This metacognitive act on the part of Kuhn helped him understand how different epistemological standards embedded in a particular social context influence the knowledge of the time, and how important this realization is for meaningful historical analysis[3]. This realization is a significant point of convergence between Kuhn, Fleck and many of the postpositivist historians and philosophers of science. Examining various epistemological standards over time, and in explicit fashion, may also be something that helps students obtain a better understanding of the nature of science and elevate their own epistemological standards. The instructional implications of this idea are discussed briefly in the final section of this work.

The next section briefly frames Fleck's historical description of changes to the concept of syphilology from the mystical to the pathological to the mainly etiological as changes to epistemological standards within the executive controller of the thought collective. The focus will also be on certain pseudo-scientific ideas that eventually played a role in the contemporary (scientific) view of syphilis and infectious diseases in general. The model developed in the next section, it should be noted, is exploratory in nature and only attempts to present a very general approach to modeling changing epistemological standards in the history of science.

Shifting Epistemological Standards

Fleck identifies three different traditions relative to the development of the modern concept of syphilis: (1) the mystical-ethical, (2) the empirical-pathological and (3) the mainly etiological, with interactions of the first two traditions resulting in the third. Each of these traditions, which Fleck associates with a thought style, will be described here as epistemological standards within the hypothesized cognitive structure known as the executive controller described earlier.

MYTHICAL-ETHICAL EXECUTIVE CONTROLLER

Toward the end of the 15th century astrology was the dominant science and played a central role in the understanding of how syphilis (at that point undifferentiated from other diseases) was acquired. It was believed that this disease was the result of some sort of 'celestial effect' consistent with the orientation and configuration of the stars and planets. But as Fleck points out, the purported cause-effect relation between astrology and disease, like any other causal explanation, can only persist if it is stylized so it conforms to an existing thought style, which it apparently did. Religion also influenced the character of this disease as it was taught that this disease was delivered by God as a punishment for lustful behavior. Together each of these factors, astrology and religion, led to a 'mystical frame of mind' (Fleck 1976, p. 3), which influenced the perception of syphilis for centuries. This condition established the 'socio-psychological' view of this new disease where the focus was on the venereal and emotive (ethical) character.

To think of syphilis in this frame of mind was to execute what we refer to as the *mystical- ethical executive controller*, where the epistemological standards or sub-judgments are governed by astrological 'insight', religious and ethical convictions, fantasy, a deep-seeded social and cultural bias, and a priori reasoning. As mentioned above, the thinking of most of 16th century physicians was constrained by this thought style and its epistemological standard. As long as these standards defined the accepted mode of thought, a modern scientific approach to syphilis could not manifest.

EMPIRICAL-THERAPEUTIC EXECUTIVE CONTROLLER

During the 15th century another competing view had emerged relative to the syphilis concept, one that focused on the therapeutic effectiveness of mercury in the treatment of syphilitic patients. As the use of mercury became more common in a number of different fields, it was increasingly used as a diagnostic tool. However, because syphilis was not differentiated at that point from other diseases that did not respond to mercury, it was observed that in some instances mercury did not work at all and even made the condition worse. Although this situation led to much confusion, it did provide a crude heuristic that could be used in an attempt to diagnose and treat a patient. Physicians focused on understanding and advancing this thought style were guided by an *empirical-therapeutic executive controller*. Operating under this set of epistemological standards involved the execution of criteria such as empirical observation, experimentation, therapeutic success or failure, diagnostic strategies, and a posteriori reasoning, which were not concepts or criteria that were well developed or had high 'beta weights' relative to the mystical-ethical executive controller.

AMALGAMATION

Regarding each of the competing traditions (i.e., executive controllers) described above, Fleck makes an interesting observation:

> Although mutually contradictory, they [each view] eventually became *amalgamated.* Theoretical and practical elements, the a priori and the purely empirical, *mingled with one another* according to the rules not of logic but of psychology (Fleck 1976, p. 5, emphasis added).

The important point suggested in this statement is that the development of scientific thought is not necessarily a sequential or linear process, but rather a dynamic combination and transformation of certain ideas. In this light, it is possible to appreciate that the mystical and ethical traditions were not suddenly expunged from the cognitive landscape, but that they provided a basis for further scientific development, even if no trace of their presence can be detected in the most contemporary of scientific theories. But this combination and admixture of ideas also represents a certain level of refinement since the act of combination implies rules for such acts. These rules, at the psychological level as opposed to the logical level, are very similar in many ways to Volpe’s theory of reciprocal inhibitions or ‘systematic desensitization’ of a strongly held view or (dysfunctional) behavior (Ayd 1995).

Initially, in the case of syphilis, this amalgamation led to more confusion and some physicians, as Fleck points out, even questioned the existence of syphilis during this period. At this time, the experimental era had begun and more physicians began to utilize this method of inquiry. Nevertheless, Fleck regards many of the early experimental attempts to address the syphilis concept as ‘useless’ (Fleck 1976, p. 7), in their ability to resolve disputes. History records that during this period of amalgamation and shortly thereafter, further debates about the nature of syphilis centered on differentiating this disease from other similar disease entities (such as gonorrhea, soft and hard chancre and tabes), identifying a specific causative agent of disease, and developing reliable diagnostic tests (such as the Wasserman reaction). Many of the competing views described by Fleck during this period resemble Kuhn’s period of extraordinary science, which represents a state of crisis and a blurring of the rules of normal science. The activities of extraordinary science are extraordinary because they will, if successful, redefine the group’s (or paradigm’s) views and commitments as to what valid and reliable knowledge and experience are; that is, to redefine the groups epistemological standards. This is why Kuhn refers to a paradigm shift as a ‘Gestalt’ switch and a change in ‘world-view’—because the world is not the same viewed from completely different epistemological standards. This period of amalgamation described by Fleck, which is consistent with extraordinary science, created the proper balance of refinement and guidance and intellectual freedom to more forcefully attack this disease, which still included traces of the ethical and mystical elements. A more recent version of these points, views, and processes would be Gell-Mann’s solution to what was called the greatest crisis of physics in the 1970’s—when there were several hundred elementary subatomic particles—by reducing what appeared to be a never-ending reductionism and chaos to a parsimonious system and theory of quarks of differing color, charm and spin through use of the eastern mystics metaphorical ideas of the four-fold way, (purposeful) whimsy, and a good dose of Freudian unconscious incubation, processing and ‘visioning’ producing one of the most major paradigm shifts (and consequent changes in the executive controller in physics) to date.

ETIOLOGIC-PATHOGENIC EXECUTIVE CONTROLLER

The success of this extraordinary period described by Fleck would later manifest as it did lead to significant changes to the thought style (or epistemological standards). These changes led to what may be called the *etiologic-pathogenic executive controller*. This new executive controller now defined meaningful medical inquiry with greater precision guided by concepts such as specific causative agents (one-to-one correspondence), reproducibility of laboratory tests and therapeutic trials (falsification), differentiation of other disease agents (differential diagnosis), and the microbe-pathological association (cause-effect relations). This new epistemological standard was the product of a far ranging thought style of the existing social strata (mystical-ethical) and the more specialized thought style of medical specialists (empirical-therapeutic), although the specific links to the former are often difficult to recognize—as airborne transmission of infectious diseases (such as tuberculosis) are difficult to recognize as descendents of the concept of miasma (mystical vapors believed to cause disease). As society began to recognize the potential and success of this new standard of knowing to decrease human suffering, it would eventually provide further support and greater expectations (explicit or implied) to the new standard.

It is important to note that the era during the transitional period outlined here roughly coincides with the rise of 'modern' science and a movement toward mechanical causation and a movement away from the venerable Aristotelian notion of 'final causes', the latter of which was marred with 'the vaguer language of essences and potentials' (Thompson 2001, p. 12). However, as Fleck's work attempts to demonstrate and which we attempt to model here, it is the interplay, interrelation and amalgamation of the vague and the precise, the rational and irrational, the logical and metaphorical, the emotive and the naturalistic that may provide the most insightful view of progress and change in science. It should be emphasized that this transition was not isolated to syphilis or a specific group of infectious diseases, but that this transition was part of a larger 'epistemic shift' and that this same type of amalgamation can be recovered from other developments that would inform the modern view of syphilis such as the transition from the doctrine of spontaneous generation to the Germ Theory of Disease, which ultimately led to Koch's postulates. Parenthetically, Aristotle's philosophical views were combined with the doctrines of Christianity during the medieval times (Ladyman 2003), which provide another sterling example of how different epistemological standards are subject to amalgamation.

Modeling Shifting Epistemological Standards

To begin the process of modeling the amalgamation between epistemological standards of different though collectives described by Fleck, a general (exploratory) profile for each of the specific executive controllers identified above is provided in matrix form in Figure 3. It will be recalled that the executive controller is situated in and is a key feature of Carifio's integrated information- processing model and theory of learning described earlier in this work. This Cartesian matrix begins by representing the epistemological standards of the mystical-ethical executive and the empirical-therapeutic executive as a relative (qualitative) function of two macro cognitive operations: metaphoric operativity (MO) and hypothetico-deductive operativity (HDO). Table II provides a summary of key cognitive features and representative theoretical referents linked to MO and HDO, respectively.

Of course any separation of metaphoric and hypothetico-deductive operativity is an artificial separation, as both operations are assumed to function and interact in parallel to varying degrees and along different trajectories among different individuals and groups of individuals with one or the other being the 'dominant' executive controller for some individuals and some groups and balanced and/or 'sequencing' for others. Even Sir Francis Bacon, the Father of Induction and philosophy of science argued for full employment of art, fiction and poetry in understanding the acquisition and development of scientific knowledge (Wilson 1998).

Understanding how these different epistemic trajectories are integrated and influence scientific progress is the aim of this work and the model described in this section, as well as an important extension of Fleck's work and thesis. Implied in the points above is the idea that a more accurate, realistic and sophisticated view and model of scientific progress (and cognition in general) is one that incorporates 'just enough' metaphoric operativity (to allow for optimal creativity and generativity) and 'just enough' hypothetico-deductive operativity (to refine, reduce, filter and modify information as 'necessary'). Carifio's model and theory of cognition, problem solving and thinking that integrate dimensions of MO and HDO has been piloted with college students, it should be noted, with promising results (see Carifio & Allen 2005).

Table II. The Basic Cognitive Features and Theoretical Referents Associated with Metaphoric and Hypothetico-Deductive Operativity

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Metaphoric Operativity

Basic Cognitive Features: Encompasses concepts such as intuition, emotion, revelation, artistic ability, creativity, poetry, society, spirituality, metaphysics, divergent thinking, analogy, fantasy, dreaming, motivation, ethical and moral development.

Representative Theoretical Referents: Metaphoric operativity is linked to Freud's (1959) psychoanalytic theory, Guilford's (1967) research in dreaming and cognition, C. S. Lewis' (post atheist) commentary on the societal motivations of science that portray science as a customized commodity for each social epoch, Kohlberg's (1981) stages of moral development, Bandura's (1986) reciprocal determinism, Merton's (1996) classic work on the reward system of science and in the sociology of science in general, McClelland's (1961) research on achievement motivation, and the view of renowned biologist Athena Andreadis (2003), who argues that science needs fantasy and science fiction to push the frontiers of progress.

Hypothetico-deductive Operativity

Basic Cognitive Features: Hypothetico-deductive operations can be thought of as the formal logic of philosophy and mathematics (e.g., transitivity and *modus ponens*) and all the functions associated with the pinnacle of cognitive development in Piaget's model of formal reasoning, which includes deduction, combinatorial reasoning, proportional reasoning, probabilistic and correlational reasoning and the control of variables (Piaget & Inhelder 1969). Hypothetico-deductive operativity as defined here also includes inferencing, which is a probabilistic/statistical cognitive activity requiring testing for verification or falsification.

Representative Theoretical Referents: The strong version of hypothetico-deductive operativity could be linked to logical positivism and the Lwow and Warsaw philosophic schools in Poland during the 1920's – 1940's, both of which rejected metaphysical speculation and equated meaningful and sustainable epistemic discourse with strict formal logic and methodological standards (i.e., pure philosophy of science).

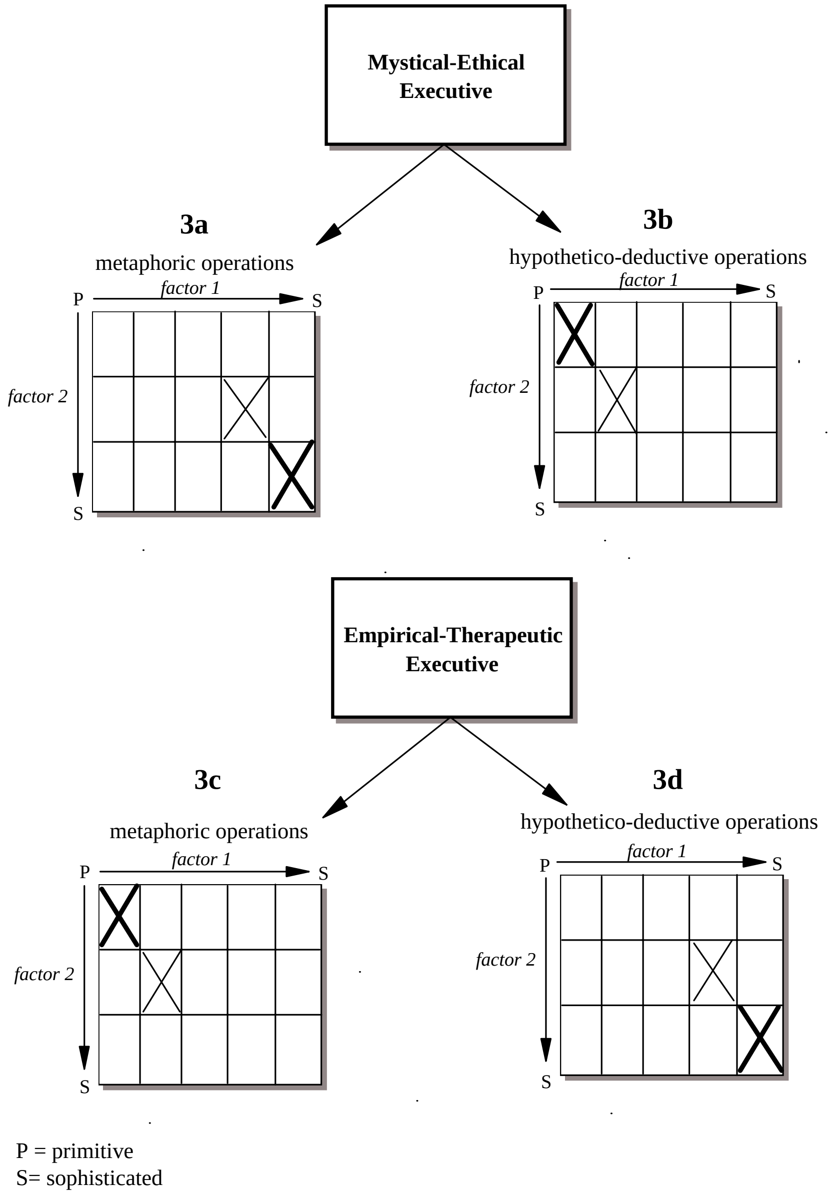

Figure 3. Macro-cognitive profiles for the mystical-ethical executive and the empirical-therapeutic executive. The thin Xs represent a shift in each executive that could represent the process of amalgamation described by Fleck.

A Cartesian Model

The two matrices for each executive in Figure 3 are based on a hypothetical 2-dimensional 2-factor model, where the x and y axes for each factor go from a low (or primitive) degree of development and sophistication to a high degree of development and sophistication. The respective points in each matrix represent vectors (versus 'scalar' points) since each operation and its associated factors involve a measure of magnitude (i.e., degree of sophistication) and direction (i.e., cognitive 'movement' along a continuum of understanding and development). The fixed points in each matrix in Figure 3 (shown by a *bold X*) are provided only as a 'snapshot' in time of the degree of sophistication for a particular macro cognitive capability within the executive of a thought collective. Together, the relative value of each of the macro cognitive features (operations) provides a crude profile of the epistemological standards for each executive. This profile will largely influence the dominance of a particular macro cognitive operation and related sub-operations for the executive, much the same way that Selfredge's 'screaming demons' function in the role of feature extraction and selection in perception, but on a much larger scale.

In realty, the cognitive process that Fleck calls 'amalgamation' occurs at the individual and group level and it is a complex, multidimensional, multifactor and 'molecular' process with varying degrees of interaction and transformation occurring between each factor and sub-factor and between each dimension with transitional probabilities from one state to another often with no contiguity requirements between states changes, somewhat akin to the dynamics and interactions between the different dimensions and states in string theory. The point to be made here is that the present model is exploratory in nature and is focused on one possible description of the macro dimensions and processes of what Fleck describes as an amalgamation between thought collectives. Future work will address the sub-domains of each matrix as well as other potential macro cognitive operations.

With the above qualifications, we can return to the simplified and idealized model in Figure 3. As can be seen in Figure 3, the profile for the *mythical-ethical executive* is sophisticated metaphorically speaking (Figure 3a) and primitive hypothetico-deductively speaking (Figure 3b). Clearly in this executive, *metaphoric operativity dominates the decision-making processes (i.e., is the loudest screaming demon)*. It is this type of executive that is often associated with proto-scientific and pseudo-scientific ideas, views, theories and perspectives, and it was this thought process (or thought collective) that largely influenced the view of syphilis acquisition during the 15th and 16th century as described by Fleck. In Figure 3c and d, the profile for the *empirical-therapeutic executive is metaphorically primitive* (Figure 3c) *and sophisticated hypothetico-deductively speaking* (Figure 3d). It is this type of executive that is often described as 'true' scientific thinking, although many science educators and historians and philosophers of science as well as cognitivists and epistemologists have long recognized the import of what here is called metaphoric operativity in scientific development and progress.

Following Fleck's approach and model, the next step is to understand the dynamics associated with the amalgamation or 'mingling' of the two executives that gave rise to the *etiologic-pathogenic executive* relative to the syphilis concept. By Fleck's account, the process of amalgamation is certainly not a Kuhnian revolution or Gestalt switch, but is more of a gradual transition or transformation in the thinking of the thought collective over time, which is consistent with Lauden's (1984) reticulated model of scientific change. In Fleck's model, the epistemological standards associated with the mystical ethical executive dominated thinking during the 16th century and the epistemological standards of the empirical-therapeutic executive would need time to 'mingle' (interact) with the standards of the empirical-therapeutic executive to create 'new' standards that would come to define the etiologic-pathogenic executive and a new thought collective. In our model, this amalgamation and transformation occurs through a shift in 'beta (dominance) weights' for each of the macro cognitive functions in each of the executives in Figure 3. At some point, the shifting beta weights for each of the interacting executives (mystical-ethical and empirical-therapeutic) reach a point where a qualitative state change occurs and the new executive (etiologic-pathogenic) becomes the dominant way of thinking. This state change results in 'developmental amnesia' that is typically observed, which is why it is important to keep a person or group 'fluid and plastic' to some degree and open to further shifts (which are becoming more rapid and life-long now).[4] Parenthetically, catastrophe theory is capable of modeling this exact type of phenomena.

In Figure3, the four *thin font X values* represent one possible shift in each executive that represents the general cognitive 'direction' or 'shift' we believe is necessary for amalgamation to occur as described by Fleck. Generally speaking, this shift involves the mystical-ethical executive becoming 'more' hypothetico-deductive and 'less' metaphoric, and vice-versa for the empirical therapeutic executive, a process which gives rise to the etiologic-pathogenic executive. Although it may appear somewhat strange and counter-intuitive to think of an etiologic and pathogenic thought collective as being associated with any type of decrease in HDO (see the thin font X in Figure 3d), the very point and brilliance of Fleck's thesis is to recognize that formal logic, operations and reasoning alone is severely (cognitively) constrained and limiting and far less generative than metaphoric operations, and that the former cannot alone account for scientific progress, development and change.

Taking into account the history of scientific development, it appears reasonable to assume that the bold font X profiles for the mystical-ethical executive (Figure 3a and b) have a weaker (less inhibiting) weeding function and is far more generative compared to the more inhibiting (yet more precise) empirical-therapeutic executive. In the case of syphilis, however, it appears that somewhere between the highly generative mystical-ethical thought collective and the more precise empirical-therapeutic thought collective, the etiologic-pathogenic view emerged and has been sustained. The 'little Hegelian amalgamation synthesis' model outlined here provides a simple and straightforward way to understand and model some of the general factors involved with the process of amalgamation in science among thought collectives using a contemporary and differentiated cognitive view as it accounts for two qualitatively different types of operations (*Metaphoric Operativity and Hypothetico-Deductive Operativity*). Further more sophisticated (perhaps predictive) models should be developed to better understand the phenomena of amalgamation among thought collectives (and thus the nature and process of scientific change), which is obviously an area of future work for us.

Discussion

This work has presented and explicated several detailed models of integrated information processing and learning, science, the nature of science and scientific change, and the nature of pseudo-science, fantastic science and proto-science, and how these latter phenomena may change and be normalized into more mature knowledge and science or be weeded from the on-going process of knowledge creation and verification. Each of the points we have presented are important and contributory in their own rights, but each also touch on a number of issues and questions that require further consideration along different lines of research, namely science education, philosophy of science and cognition. This section of the work speaks to these issues and questions.

SCIENCE EDUCATION

The *National Science Education Standards* (NRC 1996), along with the contemporary science education reform movement in general, have long emphasized an understanding of the history and nature of science (e.g., Matthews 1994). Much of the emphasis in this area of instruction involves helping students (a) contextualize science and scientific developments, (b) understand the standards and criteria that constitute scientific knowledge, (c) recognize that scientific knowledge is stable yet tentative and (d) develop the ability to distinguish scientific claims from pseudoscientific claims. These are all core epistemological issues. However, as this work points out, the nature of scientific knowledge (i.e., its epistemology) also changes over time (somewhere between the extremes of metaphysical excess and the formal logic of positivism). It is critically important, therefore, for students and future knowledge workers and consumers to understand how epistemological standards develop and change and how they influence the decisions, commitments and allegiances of scientists (as well as others). Not only does scientific knowledge change, but the methods and models of scientific inquiry also change over time and are influenced by the social and cultural milieu as well as the thought style of an era. This is an incredibly important lesson to learn because it encourages the act of meta-cognition, a cognitive skill required to contextualize science content and instruction. The instructional question is whether students could identify and distinguish different epistemological standards and criteria (and perhaps thought collectives) as well as the forces that shape these standards over time. This type of competency would certainly support the nature of science and history and philosophy of science studies movement by helping students develop the ability to identify historical and societal assumptions and biases that are inherent in scientific thinking.

A second point is that student understanding of the nature of science might benefit by realizing that through the cognitive processes of normalization and conservation science looks to reduce the myriad of phenomenological observations of the natural world—which are often grounded in highly speculative, metaphysical and pseudoscientific ideas—to the more refined, precise, rational and confirmable claims of 'modern' science. In the process, most of pseudo-scientific ideas are eliminated (or weeded out) because they do not possess the inherent heuristic to develop further as mentioned by Fleck earlier. There is great instructional value in having students attempt to characterize the epistemological standards used during different eras by natural philosophers and scientists and understanding how new data and observations influenced scientific change. For example, students could be asked to read a series of 'era-specific' case studies and to list the criteria used during the different eras used to generate knowledge, much like what is represented in Table 1. Guided by carefully selected readings and the teacher's direction, students could experience first hand how social and cultural factors mingle with the scientific to influence progress and change in science. This could also be done with basic science textbooks that provide some historical and contextual descriptions, as many now do. Because of time limitations and an already condensed science curriculum, these types of historically derived concepts may be shared across other subject areas such as history, the social sciences and even literature. In this regard, it is worth reminding science educators that the most important and influential philosophy of science movement to date (logical positivism) was a multi-disciplinary effort including representatives from history, law, economics and the social sciences as well as representatives from mathematics and the physical sciences.

PHILOSOPHY OF SCIENCE

Classical philosophy of science is focused on formal deductive logic, while the contemporary view is more sympathetic to the 'metaphoric logic' advanced in this work. Without addressing both of these established cognitive operations, only an artificial and extremely limited view of science can be constructed. Fleck's approach provides a theoretical referent from which to advance more sophisticated (integrated) models of scientific change and progress that accommodate contemporary views in cognition. By modeling and better understanding the more generative and speculative metaphoric operations in science (which may have a higher rate of return on investment compared to more formal operational models), it may be possible to develop heuristics that can be used to (prescriptively) determine allocation of funding resources, which is basically an issue of *theoretical economics*—a concern and concept implied in the work of Feyerabend and others.

Also, more research is needed to understand the process by which scientific theories, ideas and concepts transition from heresy, protoscience, or pseudoscience to dogma. This research will require the efforts of individuals trained in history *and* the cognitive sciences. The combination of history and cognition is a basic requirement in this type of project as each discipline is focused on one two central questions needed to understand this issue: historians generally ask the question 'what happened', whereas cognitive psychologists explore the psychological dynamics and factors that look to explain 'why' and 'how' something could happen. This interdisciplinary approach is something that both Fleck and Kuhn clearly recognized as important, and both continually reminded their readers that a *better* understanding of the history of scientific development, change and progress must be postponed until significant advances are made in the study of human cognition. As Fleck noted: 'A great deal still remains to be investigated empirically and discovered about the process of cognition' (Fleck 1976, p. 10). Despite tremendous advances in the cognitive sciences, we are not convinced that our understanding of the nature of scientific change and progress is much better today vis-à-vis the era of Fleck and Kuhn. One reason for this may lie with the cognitive sciences general compulsion with operative logic and a failure to truly recognize the role of other 'fuzzier' and less well defined forms of logic (such as figurative and metaphoric logic) in the process of new knowledge construction and problem-solving. This fact is disconcerting when one considers that figurative and divergent thinking—in contrast to formal symbolic logic—is associated with *excess meaning* and is therefore highly generative and creative and far less constrained than formal logic. Finding a way to introduce 'fuzzy logic' and its role in scientific progress in the classroom may facilitate a better understanding of science among students.

COGNITION AND INSTRUCTION

This paper has discussed a number of concepts and ideas that center on schema theory (such as executive controllers, epistemological standards and thought collectives). It is rather obvious that a topology (or taxonomy) of schemas is needed to classify the different types of schemas that people and groups tend to use and operationalize in different contexts and in different disciplines. This type of classification would allow for greater detail and elaboration of the model described here and other similar models. This type of taxonomy, which would be subject to psychometric validation procedures, could also provide better instructional tool and strategies for students and teachers to use in the process of characterizing epistemological standards. The last point cuts across science education, philosophy of science, and models and theories of learning and the need for them to be integrative, formalized and sufficiently detailed.

Certain aspects of all (good) science, like (all good) writing, involve weeding, pruning, shaping and editing 'prior productions'. Both (good) science and (good) writing are active and generative processes of construction and reconstruction and involve local and global changes and revisions through testing and critical review by one's self and others. There are basically two major phases (generation and weeding) to both (good) science and (good) writing, which is needed to communicate (good) science to others, and a (good) scientist like a (good) writer must have the skills and capabilities to do both phases which are more dissimilar than they are similar to each other. Further, there is a danger that one can 'write, speak, or believe' nonsense, and then revise it into further and more sophisticated nonsense, which is why meaning, explanatory theory, logic and critical and epistemological standards are needed and need to be explicitly taught. However, we do not explicitly teach or nurture the creative and generative skills in schools or professional areas, and the revisionary components and phases of science (and other intellectual modes of inquiry and knowledge creation) *together as one unit and inseparable wholeness so that both sets of abilities are developed simultaneously,* but rather we have splintered and fragmented this fundamental process and unity, which leads to poor science, bad science, pseudo-science, serious confusion and retarded progress. These same points hold for other modes of thinking and inquiry, and this view, as well as this work, gives a new definition and perspective to what is and should be meant by the term 'process education' in science and other areas. We need to develop and nurture the generative, the weeding and revisionary, the transformative, the amalgamated synthesis, and the revolutionary as one unit and process in science education as well as other educational and professional milieus.

Notes

[1] See the classic work by Eldredge & Gould (1972) and Gould (2002) for a contemporary example of this phenomenon in evolutionary biology. Eldredge & Gould's iconoclastic interpretation of allopatric (geographic) speciation via punctuated equilibrium theory challenged the then dominant view and theory of phyletic (Darwinian) gradualism. Like most 'fringe' views, punctuated equilibrium theory was initially ostracized and criticized largely because it went against established thought despite the fact that it was a logically construed view.

[2] It should be noted that Kuhn's response to critics in his 1969 postscript to *Structure* regarding the ambiguity of paradigms and his attempted resolution to the vagueness of a paradigm by introducing the notion of a 'disciplinary matrix', which is uninspiring, suggests he was not a true cognitivist since he was unable to accept and effectively defend the conceptual power of ambiguity (and differentiability) in a paradigm. This is a distinguishing feature of Kuhn and Fleck, as Fleck was more a cognitivist in this regard.

[3] This perspective was a core requirement in Giambatisto Vico's (1984/1744) model of meaningful historical examination and study. Vico believed that historians should not judge the past using contemporary values and standards and that a meaningful examination of the past should account for the historical context of the period under investigation. This act, Vico argued, requires skilled imagination on the part of the historian, as the historian needs to realize he views the past in the present.

[4] When you change developmental states, you cannot remember what it was like to think, feel or process information and other experiences in the manner of the stage you just left (or only sympathetically so and with great difficulty). This is referred to as 'developmental amnesia' and it is a standard feature of every major developmental model (Piaget, Freud, Kohlberg, etc.). This is why adults (without training) think of children as miniature adults, and it is also evidence that the 'complier has been re-written' or 'call statements have been removed'. As the main program 'works' it can issue call statements to other sub-programs (sub-routines) or programs then work as the main program progresses and pass values and results back. Development can be thought of as building new routines, adding new call statements, and deleting old call statements (but perhaps not the old routines). 'Fluid and plastic' is the standard psychology term for non-fixed, non-rigid, non-hared wired, tentative and open and adaptable to change and creative expression. 'Fluid' is Cattell's (1963) term and 'plastic' is a term derived from neurology.

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