

Towards A Standard Integrated Information Processing/ Cognitive Model of Learning.

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Kuhn (1965) and others have pointed out that when a major paradigm shift is occurring in an area, there tends to be a large number of new, competing, and most often partial models generated by the "new view" of "old" phenomena. The over-generation of models leads to several major problems that cause great confusions, which in turn stagnates the new emerging paradigm. One strategy to prevent emerging paradigm "blight" is to have professionals in an area develop and employ a Standard Model of the phenomena in question. This paper presents an attempt at formulating a Standard Integrated Information Processing Model of learning based on an analysis of the many competing models proposed and the empirical literature in this area for the past 25 years. The importance of as well as the need for an explicit and formal standard model of learning now and in science education in particular is discussed.

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Introduction

It has been pointed out by Kuhn (1965) and others (Gould, 2002, and Ashcraft, 2004) that when a major paradigm shift is occurring in a particular scientific area, there tends to be a large number of new and competing models and variations of competing models generated by the "new science" or "new view" of "old" phenomena (see also Penrose, 1989 and Wilson, 1998). This burst of creativity, somewhat akin to speciation after natural disasters in the evolutionary record (or empirical events that "wipe out" old theories), or the inflationary period in modern "big bang" cosmology (or rapid new discoveries that require new theories), tends to create intellectual and scholarly confusion and to retard progress in several different ways (Lakatos, 1970).

Rapid proliferation of new models, theories, and views (which almost always in the social sciences tend to be only embryonically **partial** and **chaotically** developing proto-models, theories and views) with no formal and explicit "**weeding**" function or mechanism, as well as the rapid development of a (proto) model, theory, or view without the same formal and explicit "**weeding**" function or mechanism, produces a great deal of confusion and misunderstanding and a great many problems that can not only make an intellectual and practical "mess" of a field and research and knowledge

creation endeavors, but also stagnates and pollutes the emerging new paradigm to such a great degree that it not only never achieves its initial potential, but actually becomes one of the major problems and impediments to high quality theory and paradigm development and research in the field. Fensham's (2004) characterization of the current state of the field of science education and science education research is a perfect example of this point, as is Matthew's (2005a and 2005b) detailed analyses and characterizations of "constructivist" learning theory. One strategy for preventing emerging paradigm (and developing theory) "blight," and chaos "so that the center does not hold (Yeats, 1916)" is to have professionals in an area develop and employ a **Standard Model** of the phenomena in question (Hawkings, 1991), which has a regularly occurring and very strong formal and explicit weeding function and mechanism. The development and use of such standards models in physics, genetics, archeology, and cosmology have been very productive over the past fifty years and have brought about much progress, clarity and coherent organization of both knowledge and inquiry. It is, without doubt, a proven approach to both preventing and solving a wide variety of problems in complex and rapidly emerging and changing areas of human knowledge.

One of the major advantages of having a standard model is that one can explicitly describe and characterize one's own view or any given view relative to it in detail, which not only clarifies the view and its similarities and difference to the standard model, but also allows more precise, efficient, and highly productive communications and evaluations of all kind to occur, and for all views to be weeded, updated, improved and hopefully advanced. Explicit formalisms, like good manners, are always needed and never go out of style, and are one of the hallmark of no longer being "pre-paradigmatic." As both Kuhn (1965) and Eisenhart and DeHann (2005) point out, standard models and 'weeded' paradigms characterize the "hard sciences" and allow long and productive period of "normal science" to occur, but that both do not characterize the social sciences, or their "derivative discipline" education, which tend to be constantly "pre-paradigmatic" (i.e., immature) and characterized by endless controversies over (alleged) fundamentals and the hegemony of (allegedly completing) partial proto-models, theories and views, many of which are fossils in the knowledge development record.

One goal of this article, therefore, is to establish the need for a standard and inclusive model of learning, and a standard model focus and movement in the social sciences, education, and science education in particular, and to describe what happens when there is not a standard model of learning available or orientation to such an approach over a forty year period. This latter description and analysis, therefore, will characterize many of the salient characteristics and problems of the fields of learning, instruction and education today, but particularly in the area of science education, which is now so dominated by "trailing" (as opposed to "leading edge") reduced marginal variants of a variety of (proto) theories, models, and views from "the cognitive revolution." Further, this article will also identify and briefly explicate the general components of a standard informational processing model and theory of learning that is inclusive of cognition, affect (emotions and sensibilities) and overt behaviors, and the wide variety of different kinds and ways of learning that most human beings are capable of and utilize very often simultaneously. As Ashcraft (2004) has said, nothing has been more intellectually and emotionally exciting, rapid, far reaching and pervasive in the last fifty years as 'the cognitive revolution' and the emergence, growth and discoveries of the "learning sciences."

The Cognitive Revolution

With McKieche's (1979) famous essay on the "decline and fall of the (behaviorist) laws of learning," Behaviorism's hold on American psychology, education and educational research efforts was officially and publicly on the wane and cognitive psychology and the cognitive revolution was in full swing and beginning to be broadly and widely considered in educational circles. Some of the early forerunners and prominent translators of selected aspects and areas of the cognitive revolution (e.g., Piaget, Vygostky, Bruner, and Ausubel), however, were established in some educational areas, such as science education, as early as the 1960's, but these forerunners were not the major architects or theorist of what is now called the cognitive revolution and the emerging learning sciences, which created several on-going and continual problems over the next forty years in these areas in terms of the proto-versions of models, theories, and the paradigm they employed and espoused. The nineteen seventies were a period of rapid first generation model proliferation within mainstream and academic cognitive psychology and the "cognitive sciences". Many of the proposed new models not only contradicted each other, but they also contracted well-established experimental facts (see Neisser, 1976 and 1982 for details). Another problem was that many of the models were **logically** impossible such as those that advocated template (rather than feature) theories of perception (see Norman, 1981), which require storage of an infinite number of templates in long-term memory, which is logically and physically impossible, as computer simulation programs (the fruit fly, empirical arbitrator, and reality check of main stream endeavors and theories) and simple direct observations clearly demonstrated. However, it should be noted, that a hallmark of these first generation cognitive and learning sciences theorists, which made them very different from many of their predecessors, were their explicit focus on developing explicit, formal and testable detailed representations of their own and their competitors models, theories and views that could be clearly communicated to others and critically analyzed, evaluated, and tested. This "sea change" in style and process, often at the insistence of many of the "hard scientists" and philosophers in these usually interdisciplinary work groups, not only set the stage for rapid advancement to productive (if temporary) periods of normal science, but also signaled the beginnings (in my view) of a shift in one (at this time small) area of the social sciences from a pre-paradigmatic to paradigmatic (as well as scientific) mode of "conducting business and doing their professional work," which was probably in strong part responsible for the "impossible to keep up with" avalanche of developments and leaps and bounds advances that occurred during the nineteen nineties.

Another problem during this period was that many of the models proposed were only "repackaged" behaviorism or associationism (see Anderson, 1983 and 1991) or neo-behaviorism (see Gagne, Briggs, and Wagner, 1988), or even worse an "apple-oranges" eclecticism (see Linn, 1986; Beieiter, 1991; and Mayer, 2003). These "repackaged" models and approaches created a great deal of confusion and a belief by many researchers (including those in science education) that they were investigating cognitive models and views of phenomena when in fact they were only investigating repackaged and revamped behaviorist models that in several instances were nineteen

eighties variants of Ryle's (1949) philosophical model of learning. This very important problem was and still is a major problem in the field, as well as in education, and science education in particular, which many leading lights and practitioners in these later areas do not comprehend, let alone the impact of this 'beta error' for a number of reasons discussed below. Further, philosophical "cognitive" theories of learning completely detached and disconnected from mainstream cognitive psychology and the learning sciences and their empirical knowledge-base began emerging during this period such as von Glasersfeld's (1989) "constructivism," which was and is as narrowly over-focused, limited, and distorting (and as fundamentally incorrect) as radical behaviorism. Such views are essentially just the other end of a "radical reductionist continuum" and suffer from all of the problems and logical and theoretical flaws of behaviorism and neo-behaviorism, a point that will be elucidated more fully below.

These repackaged neo-behaviorist models in particular did not include key model components and rejected the key principles and assumptions of the cognitive and information processing view of learning such as the **proposition** as the fundamental unit of learning rather than the **association** (see Norman, 1980 and 1981), and the existence of multiple and **qualitatively** different types of long term memory (see, Tulving, 1985 and 1986) that were and became **structured** with learning and development (see Smith, 1978; Ausubel, 1976; and Ashcraft, 2004). But most importantly was the concept and absolute necessity of **working memory** (see Baddeley, 1986) and the **executive controller** and metacognitive skills (see Best, 1989 and Lohman, 1991). And only by including a **response generation** component can the differences between competence and performance (Chomsky, 1959) be accommodated in all of its wide and varied ramifications, as well as concepts of automationization of processes and behaviors (see Sternberg, 1985; Minsky, 1986; and Montgomery, 1991). Also missing from most models and theories (and particularly as major key components) are **language** and **representational systems**, which are part of the core and fundamental essence of cognitive and information processing theories of learning and human behavior. Language, meaning, and representation systems are "nuisance variables" to behaviorist (and those of other radical views), and behaviorism eliminated these key and critical (theoretical) elements beginning with Ebbinghaus' "invention" of the "nonsense syllable" to control these factors in his research. Behaviorists have generated more knowledge about the learning of nonsense than sense, and language was more than Skinner's Achilles heel, as Chomsky clearly demonstrated. Further, it is only in the last few years has the intimate connection between language, language skills and facility, and the understanding of science and science achievements been noted (again), and a focus of concern and research (see O'Farrell, 2000 and Johstone and Selepeng, 2001). As Donald Norman has continually stressed over the past twenty years, there is no more important and critical question and factor in psychology and the field of learning (today) than the representational (system) question, and cognitive psychology could in one respect be called "representational" psychology, a characterization which reveals its deep and intimate connections to Freud and psychoanalytical theory. These deep and intimate connections are being perused by many leading-edge cognitive and neurological theorists and researchers today with many startling results and the reintegration of thought and emotions and conscious and unconscious processes and learning (see Damasio, 1999).

The next problem that model proliferation has caused (which is getting worse yearly) is that each model and its numerous variants generates experimental data and lines of research that are not easily comparable or synthesized even by meta-analytical techniques, as educational researchers in particular (and one really needs to ask why) usually do not even bother to identify which variant or version of a particular model or theory they are using or the assumptions, scope and limitations of the model or theory they are using, as if both research and theory development and modification are completely “timeless” and “time irrelevant” phenomena (see Peverly, 1991 for details). The empirical knowledge-base, therefore, is not only becoming extremely cluttered, problematic and factional in character, but it is also being filled with an increasing number of “anomalies” that seem to be very puzzling to literature reviewers. As has been reasonably well documented, both specious and aberrant data are very difficult to eliminate from discourse that is inherently factional, oppositional and contentious in character (Suppes, 1976). Unfettered and excessive subjective individualism have extremely high empirical costs and makes deciding issues and disagreements political rather than rational, empirical, and scientific, which is exactly what has been happening in science education for the past decade! Diversity does have limits and consequences. But there are other and far more important reasons why all of these problems are happening, and why a standard model and a standard models movement is needed and so desperately needed now.

The field of cognitive psychology and the “learning sciences” (as well as psychology and the field “learning theory” in general) is currently strewn with antiquated initial and interim partial and proto versions of current “state of the art” models, theories and views from the ‘wet-ware’ (neurons and brain) on up to the “functional macros” (attention, perception and so on) that are primarily of historical and perhaps academic interest. The “literature,” which is now immense, particularly in its tertiary and “translated and interpreted” forms, such as textbooks, educational research articles, and other works in science education and other educational area, is awash with out-of-date and very truncated and significantly incorrect (as opposed to partially correct) models, parts of models, theories, views, concepts, functions and mechanisms to the point where one can actually read two or more contradictory versions of the aforementioned items in the same journal, book or textbooks never mind in different journals, books or textbooks. This state of affairs most certainly creates a number of inordinate difficulties (well at least for doctoral students), but understanding how this state of affairs and the literature has come to be is of considerable importance.

Education is most often conceived to be a tertiary discipline that fishes the streams of primary disciplines for knowledge and theory that is useful to its conducting its business and affairs and achieving its goals. Educational professionals and educational theorists, somewhat like classroom teachers, tend to fish and cook alone, which has many implication in terms of what streams they fish (and when), what they catch, what they select to keep and how they prepare it for consumption and serve it up to those with whom they seek to share intellectual and practical resources, who neither fish the steams, process the raw and uncooked catches, nor do their own cooking (i.e., prepare their own translations and transformed versions). There are, therefore, many positives and negatives in this process and obviously both approaches are needed as both have strengths and weaknesses. The points of importance here, however, are (a) there are very few if any (intellectual or methodological) controls or (public) checks on this process, (b) each fishing educational professional is or can be more than a little bit of a serendipitous cowboy in terms of where and how she or he fishes, prepares and spices up a transformed concoction of some kind, and (c) models, theories, views and parts thereof of learning and learning theory in education are and have primarily been in most part created by

a process of **borrowing** more fundamental knowledge from one of more primary disciplines and integrating and transforming it into particular (and hopefully) **instantiations** for a given range of contexts.

I have purposefully used a “fishing” metaphor above to characterize this “tertiary theory” creation and representation process in order to identify one of the major causes or sources of the problematic state of affairs one finds in the area of “learning theory” today, and all of its associated problems as one encounters and finds them in the educational and science education literature today. This problem is the problem of **shot gun borrowing** and indiscriminant, uncontrolled, and often illogical **fishing expeditions** by educators and educational researchers over the last twenty years usually into the secondary learning theory literature in order to find and have in place some kind of currently popular and trendy newer (and usually uncritically examined and partial) “theoretical” framework that at least appears to be cognitive in character, even if it is that “turn of the last century show” (e.g., Piaget and Vygotsky), if not that “seventies show” (e.g., Gagne, Bruner, Ausubel, and Novak), that would make blind empiricists envious. This point is not to say that the theorists just mentioned do not have valid and still currently valid theoretical elements, assertions, (at least partial) explanations and associated empirical facts. That is not the primary point or primary point of importance here. The primary points of importance here are how these “primary” (proto) theorists are “fished,” represented, contextualized and compared to other current theory and theorists by those that employ or espouse them today. The other point of important is that chaos in the primary disciplines is bad enough, but the chaos this chaos produces in tertiary disciplines is exponential in character, particularly if these tertiary disciplines operate in a shotgun borrowing and indiscriminant fishing fashion that has little if any sense of intellectual time and place, or model, theory, or view versions (i.e., scholarship). Having a standard model of learning, therefore, is one way to begin remedying this current state of affair and pandemonium in the education and the science education literature and to prevent it from occurring in the future.

Standard Models

The above phenomena and problems are not only the results of primary and secondary researchers, theorists, and “interpreters” working alone and in isolation and/or ignoring the work and data of others, or/and refusing to modify their “core theoretical beliefs”, but they are also the result of not having a basic intellectual and professional commitment to developing a **Standard Model** of a phenomenon (see Bohr, 1934, and Hawkins, 1990) that is logically coherent, coherent with the body of experimental evidence (see in particular Martinez and Kesner, 1991), and accepted by the majority of professionals working in a given area. As previously stated, this basic commitment to developing Standard Models of phenomena is now commonplace and standard practice in physics, chemistry, archeology, genetics, and cosmology. Further, interdisciplinary approaches and work and a commitment to the Standard Model approach is also considered to be one of the major reasons why each of these areas has developed so extensively and so rapidly in the past fifty years to the point where each is currently experiencing a “mini-renaissance” of some kind (see Penrose, 1989).

The Standard Model approach has (to the best of my knowledge) never been an approach employed by any of the social sciences, but most particularly psychology, including cognitive psychology, and education. In psychology, there have been some periodic attempts to utilize something like the Standard Model approach (e.g., theories of hypnosis, types of conditioning, or transfer). However, these attempts have always been confined to micro-phenomenon and confined to small subgroups of

professionals, who tend to be somewhat insular as professionals, operating in "special interest" research groups. Part of the difficulty and uncomfortable tensions both researchers and reformers (as well as the general public) are currently experiencing is due to the lack of a "standard model philosophy and commitment" in psychology and education, and the lack of a standard information processing (cognitive) model of learning and learning processes. Part of the reason why the research on learning (in natural contexts) and instruction currently is in such a state of disarray and held in low regard is the lack of a standard models to sort out and organize the experimental literature and to guide new studies and the interpretation of issues, findings, proposed innovations and change. The "excessive individualism" and lack of (scientific) community and common value system and perspectives have in great part put psychology, education and the educational research community in the very "pickle" that is the current "experience."

Purpose

The purpose of this paper is to outline an initial attempt at formulating a Standard Information Processing (Cognitive) Model of learning and learning processes based on an analysis of the models proposed and literature in this area for the past 25 years. Once this Standard Model is outlined, the operations of its components will be discussed as well as the etiology of the components in the models and the chief principles and assumptions of the model. Where appropriate key supporting experimental data will be cited and the logical problems with the chief alternative views will be cited. The Standard Model proposed here is based primarily of the work of Bartlett, Selfridge, Neisser, Ausubel, Tulving, Piaget, Norman, Minsky, Loftus, and McClelland, and is constructivist in character in Barlett's, Selfridge's, Neisser's, Hanson's, Chomsky's and Rose's definition and construct of dynamic "analysis-by-synthesis" (re)constructivist cognitive processes (many of which are automatic and some of which are unconscious) from generative "knowledge kernels" (see Loftus and Leitner, 1992 for details) and not the constructivism of Von Glaserfeld (1995) and others, which is very different. Outlining an initial Standard Information Processing Model should, therefore, provide a stimulus and first step hopefully towards professionals in psychology and education, or at least science education, developing and adopting a consensus standard model.

The importance of having standard models of phenomena is becoming more widely recognized in all areas (see Thompson, 1985 and Reed, 1992). It is difficult to get coherent research programs without a standard model of the phenomena being investigated (Hawkins, 1991). As previously stated, standard models are ways of organizing knowledge, researching phenomena systematically and coherently, and for eliminating destructive and unproductive competition in vital areas. Standard models also have many teaching and instructional benefits for an area and discipline and their pedagogical value should not be underestimate or undervalued (see Deutchl, 1990). This particularly point is extremely important as Fensham (2004), Eisenhart and DeHaan (2005) and others (Levine et al., 2005) have written extensively on the need to develop and train new 'scientifically based' researchers and scholars in part due to the current perceived state of the field and in part due to governmental mandates in America at least. Nowhere is this more true, in my opinion, than in science education, where it is time that science educators become practicing scientists in the conduct of both science education and science education research. In this endeavor, learning theory is the core and foundational construct and thus the development of a standard and inclusive information processing theory of learning is

more than needed and overdue.

Some Preliminaries

It is not possible within the limitations of this paper to either cite or fully explicate all of the necessary key concepts, points, components, mechanism, assumptions, ideas and limitations of a standard informational processing model of learning. Explication of this standard model will most certainly take several books and explication of the each of the components and key constructs, mechanisms and theoretical elements takes chapters in these books. Therefore, I must be highly selective in what I present here, as well as in many instances overly brief on many key points and key items in to describe and elucidate the major components and theoretical elements of this standard model so that the “whole” may be seen and grasp as a “whole” if only at the macro level. I apologize for this fact and suspect that I (and hopefully others) will be presenting papers on the elements of this macro model annually for the next decade But presenting an initial general description of the macro standard model is just that important, I believe. I also apologize for some of the materials below being redundant to my presentation of some of it elsewhere (e.g., Carifio, 1993 and Carifio and Perla, 2005), but I also believe that it is important for macro standard model to be understood that certain information about it is presented all in one place. With these points in mind, I will address a few initial preliminaries and then proceed to the standard model and its description and explication.

I have chosen an **information processing** model and theory as the backbone (or general framework) of the standard model I have developed, as this paradigm and theory is more general and inclusive than “cognitive” (and other) theories and models, and this framework and paradigm is capable of modeling dynamic, real-time, chaotic and changing learning processes and outcomes. It is also a model and theory that is consonant with neurology and the “brain-sciences” currently to which any standard model should be connected and consonant in some fashion in my view to stay “real and grounded” as well as practical. Information processing models and theories seeks to depict and explain the communication and exchange of information between two or more “entities” (however framed and at whatever level of focus) and it is a framework that is currently used to model and explain the interactions between cells, atoms and even subatomic particles as well as human beings (see Neilson, 2002, Lyold and NG, 2004, and Mattick, 2004 for details). Information in information processing models and theories is assumed to be at least (partially) meaningful information (or “memes,” see Blackmore, 2002), typically, which implies that the information being exchanged has some kind of inherent and autonomous “deep” structure embedded in an “envelop” or “wrapping” (i.e., “surface structure”), which may or may not have been constructed intentionally (and may even have unintentional components or elements, and is not necessarily a “constant,” and may be changed by various mechanisms and procedures at each step or stage in the exchange process, which are often multiple and occur in mico and macro cycles across a complex exchange event. The model can handle the processing of ‘meaningless’ information or ‘white noise’ (and thus random trial and error learning, for example), as well as information that is initially (subjectively) “meaningless’ but becomes ‘meaningful’ over time and a series of exchanges (and thus concept formation, for example). Meaning is both subjective and objective in information processing models and has both subjective and objective components (with each having their separate but overlapping long term memory stores).

Subjective meaningful information, for example, is “my personal dislike and disbelief in drugs.” Objective meaningful information, for example, is the observable and reliable effects the drugs I dislike and do not believe in have upon my body and my behavior no matter how I “construct” (or interpret) the world or the events associated with my taking them to be and the replications of these effects in the bodies and behaviors of others (despite their subjective views or understanding of biochemistry). Energy exchanged between two subatomic particles is objective meaningful information. My denial (or lack of awareness) of the existence of subatomic particles would be subjective meaningful information. Information in information processing theories is a complex construct which needs a great deal of explication(which is beyond the scope of this paper), but it implies a “semantic” (i.e, meaning system) of some kind as an inherent component of the processor (which was Chomsky’s whole and correct point) and semantic or interpretive processing events as part of the exchange that may be highly “plastic” or automatic or both simultaneous. It also implies a definition of information and a particular subset of information called knowledge, which is a particular kind of “validated” information with warrants, more akin to Popper’s (1934) “objectivist” account and epistemology than other views.

As we now know, the human brain is highly differentiated with several qualitatively different information processing units and subunits which operate upon and transform components of information complexes simultaneously (e,g, see Gazzaniga et. al., 1998 for details). We are, therefore, many “brains” and “many capabilities” simultaneously “in one,” and we are capable of learning in several qualitatively different ways ranging from unconscious and automatic learning processes of several different kinds to automated processes (and habits) that mediate the processing of information and a variety of learning to highly conscious and complex forms of different kinds of “logics and reasoning”, decision-makings, creations and confirmations which often qualitatively change the information processor and her or his understandings, knowledge, powers, and capabilities (see Carifio and Perla, 2005). One of the most important and significant contributions of Robert Gagne was not his erroneous theory of learning hierarchies but his formal explication of “The Variety of Human Learning”(1976) and learning processes, which has since be all but forgotten in many educational areas including science education, but which should have been the death knell of “**monotheism**” in the field of learning and the “monotheism battles for hegemony” that were wages for over a century and are still being waged in various “villages and hamlets” in education today. There is no one underlying and universal learning process or way of learning that characterizes and encompasses all cognitive forms of learning and development, let alone all of the “non-cognitive” forms of learning and development, and that is a fundamental fact any particular model, theory or view of learning of whatever kind must explicitly accommodate and address. Therefore, the standard model that is developed should be capable of describing, modeling and explaining the different kinds and ways of learning we currently know. More will be said on this point below, but this point is most definitely a ‘book of its own,” given both the radical and overly reductionist monotheistic tendencies in all areas of education currently, but science education in particular, which has been on-going since the 1960’s.

Trying to integrate a number of qualitatively different and to some degree incommensurate (sub) models, theories and views of learning into a more comprehensive (macro) model poses a number of somewhat daunting problems and

difficulties because one cannot just ignore or dismiss observable empirical facts in many cases (such as reinforcement and its effects), but rather one must re-interpret and “re-theorize” them to incorporate them into the new and standard macro model. For example, **reinforcement** is defined as “effects or consequences information of various kinds” that is **additional information to be processed by the information processor** (which may or may not happen or may or may not successfully happen for a variety of reasons). This redefinition and reinterpretation of reinforcement not only can explain “schedules of reinforcement,” but also allow reinforcement to be distinguished from feedback, which contains or should contain “corrective information” under conditions of consequences or no consequences. There are many such redefined elements in the standard macro model presented below. This same point holds for several “learning myths” that need to be dispelled, as they just refuse to go away.

For example, it is typically said that all theories of learning hold that the learner must be “(highly) active” and actively and overtly engaged in the processing of information and the construction of understanding, meanings, and new behaviors or learning simply will not occur or occur poorly. This claim is indeed true in many situations and contexts but not in all situations and contexts, or all situations and contexts involving cognitive or intellectual learning. One of the most powerful and fastest ways human being learn and learn enormous complexes of structured information is through **observation** and **observation learning processes** (Bandura, 1986), which may be and often are highly passive and unconscious, but are typically improved with guided, focused and conscious observation and reflection. A learner, therefore, does not necessarily have to be ‘active’ or ‘constructing’ for learning to occur or even awake for that matter.

This same point holds true for what Ausubel (1968) called the verbal transmission model of learning, which he subjectively estimated accounted for about 80% of what people learned in their lives, as there are very few direct and active experimental events in our lives and we all seek to profit from the experiences of others, or at least the wise among us. Therefore, that some types of learning require ‘high activity’ and active overt engagement, it does not necessary follow that all learning requires this condition or characteristics (which is not true) or that learning that does not require the learner to be “highly active” is by definition problematic, defective, passive and non-meaningful and to be shunned and avoided (which is equally not true). This same points hold for similar over-generalizations and slogans such as “all learning should be fun” (some learning is fun but a great deal of learning is not and never will be and that is a fact that all learners need to know and get on with it), and a variety of similar “motivation,” “relevancy,” “organization,” “overt active manipulation” and “discovery” type statements. All such claims and slogans need to be highly differentiated and contextualized and their limitations and scope clearly and explicitly stated, otherwise we are going to remained mired in “creationist” learning theories and views, with all of the double meanings and puns intended. “Creationist” learning theory is a problem currently in science education, which Matthews (2005a and 2005b) has described and elucidated in detail.

Along these same lines, my next point concerns common every day phenomena that any theory of learning (standard or otherwise) needs to be able to adequately explain. For example, the downfall of behaviorism had more to do with the theory’s inability to even inadequately explain simple every day phenomena such as one’s ability to understand a truly new sentence one had never hear before, laughter and

why we laugh at jokes, puns and witticisms, trauma, observational learning, and learning that occurs without conscious awareness (all pointed out by Chomsky in the “Great Debate”), than with all of arcane and convoluted arguments made and value positions taken. Relative to the “laughter test,” it is more than somewhat interesting to both view and understand laughter as sub-microscopic ‘theory’ or representational (system) change, so that when one’s working model (current construction) all of a sudden does not fit the currently flowing data stream (observation) and is fatally contradicted by the subsequent data that presents itself, it is the biggest joke and best laugh of all, as any scientist will tell you. Most agree that observation is very important to science and science education, but laughter and humor being perhaps equally important to the conduct and the teaching of science tends not be a phenomenon that has inspired a plethora of catchy slogans and recommendations from science educators (in my experience of the field). I will try to point out more of these common and every day learning phenomena below (such as how and why to overt and covert behaviors become organized and organized in time according to the view being considered) as explaining such simple phenomena provide both good and extremely cheap (scientific) tests of any given model, theory, view of even philosophy of learning.

My last two “preliminaries” concerns emotions and personality, which I believe must be part of any standard macro model of learning for a variety of obvious and less obvious reasons, as excluding them would be similar to excluding the “dark matter and dark energy” in the universe if we were physicists or cosmologists. Emotions are defined as “fuzzy” cognitions of a very particular kind; namely, rapid and global cognitive appraisals of information being processed by the person with an equally rapid physiological energizing or de-energizing **spreading activation** component related to the immediate as well as future well-being of the person (see Ekman and Davidson, 1994 and Johnson, 1999 for details). Using this latter construction of emotion, **motivation** is treated as a special and specialized (developmental) emotion in my standard model with both extrinsic and intrinsic cognitive appraisal and energizing and de-energizing components. Further explication of this particular point is beyond the scope of this paper.

There is a great deal of recent real-time PET scan information that indicates that both external and internal information that is being processed is initially “preprocessed” in the amygdala (the emotional processing center in the brain) slightly before it is processed in the higher order cognitive centers of the brain where this preprocessed information (and resulting emotions and emotional information) is then integrated with the cognitive processing that is being to occur (see Shreeve, 2005). Emotions, therefore, are the raisons and spices in the cognitive muffin that is being made as the processing of information unfolds to its conclusions. As such, emotions have many and various effects and simply cannot be ignored, excluded or dismissed from consideration and must be included in any standard model in my view. Mandler’s (1989) very detailed theory and model of emotions and how they arise and effect information processing is currently the best choice for this component, in my view, as well as my restatement of Polya’s model of problem solving in terms of modern information processing theory and Mandler’s theory of emotions for understanding the development and execution of difficult and complex intellectual behaviors, which is the essence of science, and understanding science and conduct of science as well (see Allen and Carifio, 2004 and Carifio and Allen, 2005 for details).

Personality and personality theory has undergone extensive redefinition and

reformulation in the last decade, and personality is currently defined as relatively enduring characteristic ways of processing information (see Calvin, 1998). Personality must be included in a standard model, in my view, because it is one of the core constructs of the self, consciousness, individuality, individual differences, the subjective and the social self and the self in relation to others as well as the world. Personality is also the component that “personalizes” the model and theory and allows one to consider and address “subjective knowledge” and subjective aspects of alternative conceptions, and it connects the model to psychoanalytical theories, and thus emotions, conflict, development and culture in a very broad and inclusive fashion. The four macro personality types on the Apgar scale are observable within 24 hours of birth and correlate with adult observations of the four macro personality types at about $r=+.80$. Even though the current mission in education is “success for all,” the “all” are not carbon copies or clones of each other (a hidden assumption in many models, theories, views and practices) and operating as if they were is not only going to produce some serious interaction effects but also result in just “success for some” masked in overall averages. Lastly, personality is an “executive controller” function and component, which makes it very different in kind and character than information and knowledge represented and stored in long-term memory schemas.

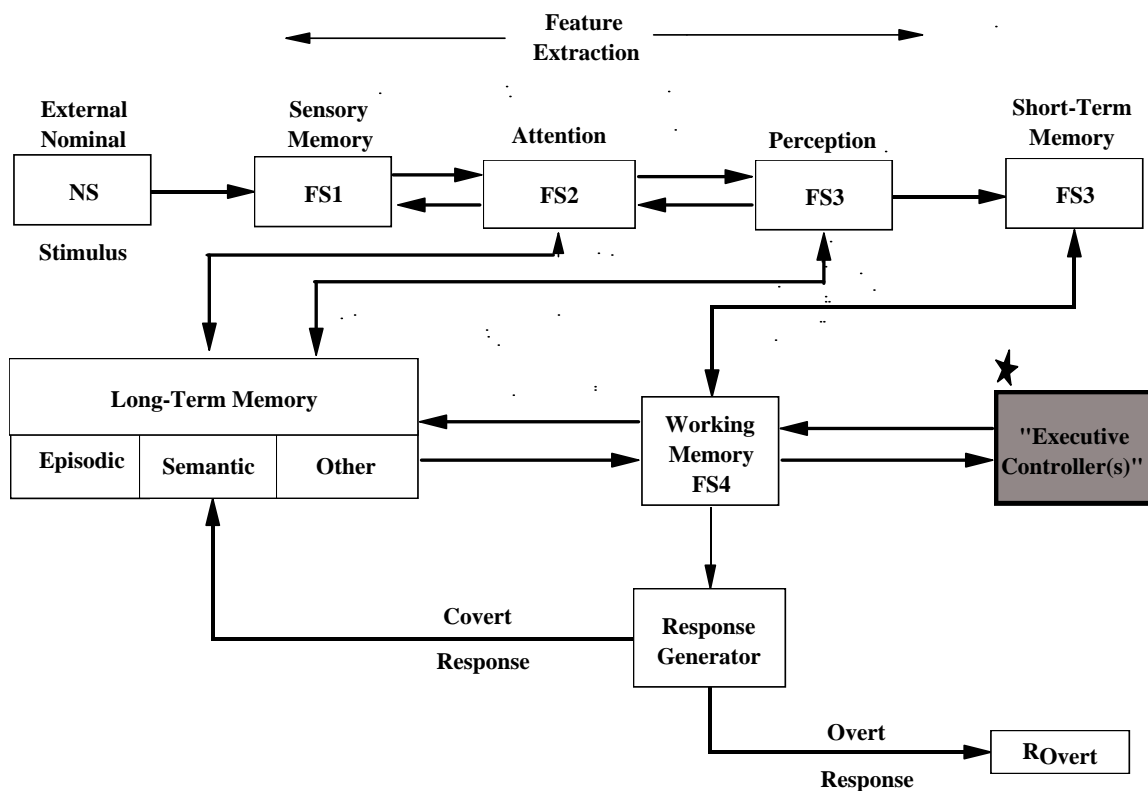


Figure 1. Carifio's Standard Information Processing Model of Learning

Table I. Five Basic Principles and Sub-Components of Carifio’s Integrative Information Processing Model and Theory of Learning.

1. Cognitive Limits:
<ul style="list-style-type: none"> • 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:
<ul style="list-style-type: none"> • Any given person is only partially knowledgeable about anything / most things (almost always). • Everyone is only <i>partially rational</i> 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, <i>degrees of partiality</i> (of knowledge and rationality) and the frequency and length of these intermittent periods and activities.
3. Schemata:
<ul style="list-style-type: none"> • 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” or events that have happened. • Despite the fact that there are a number of different types of schemas (e.g., cognitive, meta-cognitive, procedural, and affective), the fundamental units of all schemas are concepts and principles and their inter-relationships, which are the key and critical elements in schemas. • 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:
<ul style="list-style-type: none"> • There is not a “single” process or “processing” at any given moment in a processing system, but rather <i>a multiplicity of different processes and processings</i> 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. Processes occur in recurring micro-cycles, which operate by and bring about spreading activation, which may be deep or shallow (see Collins and Loftus, 1976, Gazzaniga et. al., 1998).
5. Executive Families:
<ul style="list-style-type: none"> • 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 colosum (see Carlson, 2002, Shreeve, 2005). • Each of these executive processors in a person’s family of executive processors is a generative specialized compiler <i>with its own representational system, language, logic and set of functions and commands which goes through development level and customization</i> (Cattell’s [1963] crystallization) over time through interactions with the outer and inner environment (Minsky, 1986). Each of these executive processors in a person’s family of executive processors goes through developmental stages and phases across the life span on an individual, “subject-matter” related, and somewhat autonomous as opposed to “global across all processors” basis, as do other model components. One must always indicate the developmental stage of model components when discussing, using, particularizing, or instantiating the model in a given context. • 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).

Figure I presents my initial attempt at a Standard Integrated Information Processing (i.e., “Cognitive”) Model of learning and learning processes. Each of the components and sub-elements of this standard model will be briefly defined and characterized below, but many of the general characteristics and assumptions need to be addressed also as the discussion proceeds, as these general characteristics and assumptions are not given or apparent in the diagrammatic representation of the model given in Figure 1. Consequently, Table 1 gives a summary of five of the key basic principles (core constructs) and sub-components of my standard model.

As can be seen from Table I, A critical underlying feature (or core construct) of my standard 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 construction**, 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 system that implements model (i.e., the human brain and its distributed neuronal and memory systems). It is also worth pointing out here that both information processing and cognitive psychology are primarily concerned with **understanding behavior**, especially behaviors that have the greatest survival value in a complex, rapidly and constantly changing environment, as this is a common misconception (as opposed to alternative conception) about both of these theories and approaches. Thus, although my model often focuses on individual acts of information processing and learning for illustrative purposes, its features are easily extended and applicable to groups of individuals and their **behaviors** both individually and collectively. Thus the model may be used to do the “psychology or social psychology of science and/or philosophy,” as has been demonstrated elsewhere (see Carifio and Perla, 2005).

Another key feature (and core construct) of 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. My view in this standard model, 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. My standard model, therefore 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 my standard 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 often makes 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)

If any one understands the importance of the irrational and metaphoric (as opposed to logical) operativity to science first hand it is, without doubt, Gell-Mann.

Schemata

The idea of a schema (pl. schemata) is central to my standard model of information processing (as it is indeed to all of the cognitive sciences) and this core construct needs to be understood in depth 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, meta-cognitive, procedural, and affective), the fundamental units of all schemas are concepts and principles. Further, unlike other theorists in this area, my model 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 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 schemas 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.

Schemas, whatever their type and/or structure, are highly conservative as their principle function is to organize and reduce information. In fact, if schemas 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). Speed of processing and thus speed of responding is one of the reasons why schemas tend to become organized (note well, this is an inference for a wide variety of data and not a direct observation), and semantic knowledge schemas in particular and in general tend to become hierarchically organized, so that their most important and critical knowledge kernels (given their current state of development) are retrieved and access first in the spreading activation processes that occur during "pre-processing" (attention and perception) and "deep processing" in working memory. In real-time, activated schemas are accessed in "segments" and "pages" as needed and as can be accommodated by a particular memory story.

Schema are guided by normative rules and exception rules, which mean that schemas 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 and schema element 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 ‘meta-cognitive’ 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 schemas have episodic (procedural) and semantic (declarative) instantiated forms and components. All schemas (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 schemas is not explicit in most theories except my standard model. In terms of academic knowledge and academic learning, this and critical distinction is a very important characteristic as well for pseudo and fantastic (science) schemas and beliefs, as the ‘inner core (of explanatory elements)’ of these latter ‘alternative schemas’ are usually radically different from the current (scientific theory or consensually held) 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 schemas are to some degree ‘constructed’ and ‘socially mediated’ and ‘social’ entities between schema holders and the (fuzzy) communities they form. Schemas 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 schemas 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.’

Schemas 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 schemas. 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. Schemas generally change in one of two ways. The first way schemas can change is through assimilation (local small-scale changes). This type of change 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 (one reason why you do not have stored in long-term memory everything you have ever experienced). 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 posited 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 rife 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 elsewhere (see Carifio and Perla, 2005) 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, which are of critical importance. In short, schemata directly or indirectly influence every aspect of the information-processing model of learning presented in Figure 1.

Parallel Processing

One of the most important aspects and core constructs of my standard information processing model of learning are the bi-directional arrows in Figure 1, which represent the feature and core construct of **parallel processing**. Parallel processing involves any mental (i.e., brain) processing where more than one (neurological) operation (on components of or the same information) 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 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 and information processing than had previously been acknowledged. There is not a ‘single’ process or ‘processing’ at any given moment in time 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 features and core constructs in mind we may return attention to my standard model.

Basic Components of the Processing System

The front end of my standard model is focused on **feature (critical information components) extraction** and is responsible for the initial processing of the **nominal** (external) **stimulus** (S_n) into the **functional stimulus** (initial internal representation that is further processed), although the initial “activating stimulus” in this model does not have to be and most often is not external, but is internal and a passing thought, recollection, imagining, musing, feeling or rumination that is

serendipitous or (purposefully) self-initiated. One does not want to fall prey to the Locke, Hume and behaviorist's category mistake of all knowledge and causes being external and first in the senses. Sometimes knowledge and cause are and sometimes they are not (as Freud in particular so clearly demonstrated). **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 very 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 processes, which are features and functions that reside in some developed form in the executive controller. As stated above, Hume and Locke were out and outright wrong about 'all sensations' existing in the senses. All ('primary') sensations and information are not 'in the (external) 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. Modern CAT, PET and MRI scans have clearly shown that is this not the case (see Gazzaniga et. al., 1998 for details).

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., schemas) 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 having a particular 'theory' or appraisal and a rival hypothesis or a hedging one's bets simultaneously present, which accounts for very rapid shifts in attention with new disconfirming information). Consequently, schemas influence what an individual attends to (and makes major or minor) and what is **ignored**, which is equally if not more important. Attention, therefore, is a **relational phenomenon and process** (focal to peripheral and the elements within each), which is a characteristic of attention that is often missed or ignored but which is often critically important as both Gestalt psychologists and computer simulation of cognitive processes have demonstrated. Attention initiates the processes of **spreading activation** in the brain, as sensations and the operations of sensory processing can be blocked and ignored by the brain reticular activating structure even though they are "occurring" and are "real," as we all know when we finally realize that our hair is on fire. Stopping, limiting, muting or shutting off of processes, therefore, are as important as activating them, and **simultaneous** activation and shutting off of signals (messages) and processes is the basic process by which all neurons work.

Perception is a dynamic and active process that involves further encoding (interpretation, expansion, elaboration, and enrichment) of the functional stimulus (Sf2) with information derived from schemata stored in long-term memory. Perception involves construal, making sense of new information and **infusing initial meanings of various kinds** into the function stimulus at this point. This encoding and infusion **significantly adds to and leads to further changes in** the functional stimulus (Sf3), which are temporarily stored in **short-term memory**. Perceptual process, moreover, may feed back to and redirect attention and attentional processes, and such **feedback loops** are a part of and occur through this model and the processing of information. Perception is also both **a conscious and unconscious process**, which is not all that hard to understand given that attention is both focal and peripheral simultaneously. There is both focal and peripheral perception in my standard model with peripheral perception typically being so rapid as to appear to be unconscious (but not unperceived), as a variety of modern CAT and PET scan studies have shown (see Demasio, 1999; and Shreeve, 2005). Further processing may occur with very limit perception functions occurring and in fact almost no perceptual functions

occurring at all as both rote learning, memorization and the learning of nonsense syllables attest. Information, therefore, does not necessarily have to be highly meaningful to be ‘thought about’ in a limited and partial form or way. One of the major differences between ‘novices’ and ‘experts’ in a particular area, it should be noted is their very qualitatively different attentional and perceptual processes. Novices and experts pay attention to very different features in the nominal informational complex (i.e., stimulus) and they construe and infuse what they do pay attention to with very different schemas. Therefore, even if they had “equal thinking skills and abilities” (which they tend not to have), the products of **their** reasoning and thinking would tend to be very different as **they are not operating on the same functional stimulus** even in the fuzzy sense of the term during the reasoning and thinking stages of the information processes process. Thus the critical importance of the “feature extraction” process in learning and instruction and why the old fashion Socratic method have been continually successful in various contexts even in the modern politically correct form.

Short-Term Memory

Short-term memory is the very limited temporary holder of perceptually encoded information (FS3 and FS3 updates). It is a buffer that mediates the processing rate differences and processing capacity difference between two major processing components (perception and working memory). The limited storage capacity of short-term memory is Miller’s famous 7 ± 2 “chunks” of information in adults, which is approximately 3 ± 1 chunks in children and professors. Information in short-term memory must be ‘rehearsed’ and “refreshed” constantly to be retained or it will be lost and forgotten and obliterated by newer information streaming into to it. The forming of conceptually “larger” or more abstract information “chunks” is the basic strategy of transcending and over-coming the limitations of short-term memory and the bottleneck it posed in the processing of information by the other more power systems before and after it. Short-term memory more than any other model component demonstrates the necessity (both logical and empirical) for conceptualizing and abstracting to overcome real-time processing difficulties and limitations as well as possibly how and why these capabilities emerged, although long term memory contains similar lessons and demonstrations. Short-term memory illustrates the critical importance of pace and pacing in formation processing and learning and the limits and limitations of “speed of information presentation” and “speed of learning,” which are variables that tend to be ignored by many theories of learning and instruction. Norman (1981), Ellis and Hunt (1993) and Ashcraft (2002) are excellent sources of the details and mechanisms of attention and several other model components, processes and mechanism. One could consider working memory or long-term memory next. It has been my experience, however, considering long-term memory next is most helpful.

Long-Term Memory

Some of the perceptually 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 long-term memory is chronological, historical, and time and time relationships oriented. Episodic long-term memory

specializes in storing “events” information and information and groups of sequential events or episodes. Such ‘groups of sequential events’ might be a mental recipe or algorithm for doing something or an actual motor sequences of behaviors such as dancing a waltz or a tango (non-interpretatively). Thus, episodic long-term memory is something times called ‘procedural’ or ‘motor’ memory, but it is about far more than (sequential) “procedures” and “knowing how,” which is a very truncated view of episodic long-term memory. Episodic long-term memory also stores personal, autobiographical, emotional, and story memories. Episodic long-term memory is not very abstract or general in character and tends to be very specific, concrete, and oriented towards particularity. Episodic long-term memory is only semi-logical and often “figurative” in its operations, and it often operates in a “rote” fashion, and automatically and unconsciously, and in terms of images, icons, signals, and cues. Information in episodic long-term memory is usually stored in narrative or story-based schemata or ‘scripts’ that are chronologically organized, tightly bounded with little transfer, and concrete. Forgetting most often results from “breaks in the chains” of cues, association and relationships that make up an episodic schema, particularly if the chains are “long and complex” or too great of a ‘memory load.’ Episodic long-term memory is considered to be the most basic type of long-term memory as it is present in animals as well as humans. It was rightly construed by Jensen (1972) to be what he called Type I long-term memory with semantic long-term memory being Type II. Children in the pre-logical operations stage of development and below tend to have primary episodic long-term memory as semantic long term memory is something that develops over time with neurological growth, the acquisition of language, logic, a wide variety of important concepts and other representation systems.

The storage of information in and retrieval of information from episodic long-term memory is also dynamic, reconstructive and always changing and episodic long-term memories are not fixed or “stamped-in” and non-errorful as the behaviorist contend, as was convincingly demonstrated by Bartlett (1932) famous War of the Ghosts experiments, the plethora of eye-witness research (e.g., Green and Loftus, 1982, 1997, and Mazzoni and Loftus, 1998), false memory research (Loftus, 1981, 1996, and 1997), and Pinker’s (2002) review of the literature and theory of the “blank slate” model and theory of (episodic) long-term memory. It should be noted that behaviorists contend that there is no such thing as semantic long-term memory (i.e., it is a chimera of the cognitive perspective like many other chimeras of this perspective), which is a position that is held by many radical behaviorists and neurologist today despite the overwhelming evidence to the contrary (see Pinker, 2002 for details).

The fundamental elements of episodic long-term memory schemas are primarily very abstract and somewhat fuzzy generative memory kernels (Greene and Loftus, 1982, Tulving, 1986, Loftus and Lietner, 1992). These fuzzy generative memory kernels interact with the capabilities of the executive processor during recall to inferentially and deductively reconstruct a reasonable and plausible version of a “story,” sequence or events or behaviors, or similar “chronology.” These generative, reconstructive, and elaborative are why there is variance in the information (and particularly details) recalled from episodic long-term memory from occasion to occasion, even with practice and over-learning, and why these memories are not “inert” (particularly if they are ‘meaningful’ rather than ‘rote’ long-term episodic memories) and markedly change over time, even though not actively recalled (activated) for long periods of time, as Bartlett observed. This process and dynamic is also why there are false memories; namely, current suggestions and suggestibility provide enough critical (and believable) cues to the executive processor to have the capabilities of the executive processor reconstruct a plausible and reasonable memory of the experience and events that never occurred (see Loftus, 1996 and 19997). If one thinks that this is a rather frightening state of affairs, then one should note that the converse side of these dynamic and fuzzily generative episodic memory processes is how one typically tends to characterize a “good and critical reader and observer,” and active and automatic

controlled and constrained elaborations, inferences, deductions, constructions and reconstructions are the very meta-cognitive skills and processes that characterize high quality thinking and what we want to develop in those we teach hopefully. Most information in long-term memory, therefore, is not forever there in its exact and initial form of storage and ‘inert’ or inert or exactly the same for very long.

Episodic long-term memories also become culturally and personally “rationalized” and change in various ways over time via unconscious and automatic processes and are not the highly stable and unchanging information sets behaviorists and other claim them to be. These facts have many important implications relative to learning and instruction as well as in terms of observing and first-hand and personal observational research. Another memory myth is that we have stored in long-term memory everything we have ever experienced. First, think of the number of neurons this would require and the amount of daily energy intake it would take to maintain all of these memories. Next is the basic fact that the vast majority of one’s neurons are not devoted to memory and cognition but are devoted to autonomic nervous system functions. So one’s memory does not have anywhere near the storage capacity one might think, or is claimed in so many textbooks and articles, and is in fact quite limited. Lastly is the fact that the majority of what we experience never makes it to long to term-long memory and that it takes roughly 72 hours to form a long-term memory as it requires the synthesis of new proteins and the alternation of synaptic and other neuronal structures. When one (semi) permanently learns something, one alters and physically changes one’s body (i.e., one neurons and their constituent parts). This is one of the reasons why most learning (except trauma) takes time and there is a “learning curve.” It is also why one is actually “built to be somewhat resistant learning,” as one cannot be physically altering one’s neurons (body) back and forth willy-nilly ever minute or so. It is also why working memory temporarily “keeps” potential new memories “stored” in a refreshable form for roughly 48 to 72 hours so they are available for conversion to (semi) permanent status if this appears to be what is needed for the well-being or successful functioning of the person. This point is also why there is initially a “learning inertia” when one begins new learning tasks that meta-cognitively wise learners learn to push themselves through. All of these points need to be explained more fully but each are currently beyond the scope of this paper. However, as Norman (1981) and others have continually pointed out, every theory, model, and view of learning theory of memory, which is often implicit and hidden rather than explicit and clearly stated, and exactly what that model or theory of memory is critical to understanding and evaluating the model, theory, or view of learning in question and its fundamental correctness and validity. Asking what model or theory of human a particular model, theory or view of learning has, therefore, is one of the very first questions one must ask and answer and particular so for any standard model of information process and learning. Lastly, given how limited long-term memory is, and what it takes to form a permanent long-term memory (or change a permanent one), it is understandable why long-term memory is highly selective, dynamic, generative and essentially reconstructive with some reconstructions be much, much more reliable than others.

Figure 1 indicates that episodic long-term memory is one of the several different kinds of long-term memories. Behaviors and many other views contend that we have only one kind of long-term memory and that all long term memories are the same and essentially episodic. Modern neurology, cognitive psychology and information processing models do not hold this view but rather contend that we have several different kinds of long-term memories which are qualitatively different from each other, are organized and operate differently but work together in a loosely couple, parallel and fuzzy fashion. The experimental and observational neurological evidence overwhelming supports this view and the second major type of long-term memory is **semantic long-term memory**, which is sometimes called declarative long-term memory but is much more than ‘knowing that.’ The story of semantic long-term memory is one of the most

fascinating in psychology and neurology covering a 75-year period of skirmishes and resistance until Tulving's (1976) landmark research and book and Quillian's (1978) empirically cross-validated with humans questions answering computer simulation of a semantic long-term memory schema and knowledge structure. From then on, there was no real looking or going back by anyone who was keeping current with the mainstream and by the late nineteen-nineties almost all attempts to simulate semantic long-term memory using "associationist" or similar principles and models (e.g. Anderson, 1989) had been abandoned. It is note without note that the next great "leap forward" in the internet is both touted and called the move to the **semantic** web and for good reason.

Semantic (or abstract) long-term memory represents the long-term storage of your general world knowledge including different concepts and their relations as well as well as your knowledge of different subject-matter areas or disciplines. The schemas of semantic long-term memory specialize in storing abstract concepts that are organized in structured conceptual networks, which also includes, principles, facts, theories, and associated information and their inter-relationships. Semantic long-term memory schemas tend to be somewhat more stable, less dynamic and less reconstructed than episodic long-term memory schemas. Schematic long-term memory schemas tend to be free of 'time and place' information and "personal" information (one of their 'hallmark' characteristics). Few people, for example, can accurately recall all of the events surrounding their learning of " $Y=bX+a$ " and usually start laughing when question about what they were wearing at the time, what the weather was, or what they had for lunch (but can answer all of these questions very accurately about "their first kiss"). The information stored in semantic long-term memory, therefore, is highly decontextualized and is more "objective" than "subjective," and resembles Popper's notions of knowledge more than Proust's or Joyce's. So in this standard model, both views are correct and incorrect at the same time, as the model posits both views and both capabilities. In 'experts' long-term semantic memory schemas or networks appear to be hierarchically organized, given the **indirect observations** that have been made of them (i.e., recall protocols, concept maps drawing, question answering and computer simulations). No memory schemas of any kind are directly observable yet. This particular point is a very important point because most of what we have to say about long-term memory schemas is inferential and not direct fact, and one must always keep this point in mind when talking about schemas and schemas theory currently. Semantic long-term memory appears to work by a top-down processing mechanism rather than a bottoms-up mechanism like episodic long-term memory. We are, therefore, capable of both modes of processing, which are highly context dependent in terms informational demands and memory systems demands. The problem is when there is a mismatch between the demands of the task and current memory systems states or capabilities.

The long-term semantic memory schemas of experts also appear to be highly developed, detailed and logically constrained, and highly similar from expert to expert in an area, particularly relative to the key concepts, principles, theories and facts and their **stipulated** inter-relationships which is the most critical information in schemas. The semantic long-term memory schemas of novices tend to be missing key concepts, principles, theories, facts and associated information and to include the concepts (and so on), which have little or no relevance to the subject matter or discipline in question or are in many instances actually antithetical and contradictory to it. The semantic long-term memory schemas of novices tend to be idiosyncratically organized and they also tend to have few relationships between the elements in their schemas and many erroneous relationships. The semantic schemas of novices, therefore, tend to be **partial schemas or much more partial than the partial knowledge schemas of experts in the area** given the current state of knowledge in the area, which is the determining factor on completeness, coherence and logical consistency of the schema. My points here are three. First, "laundry lists" of concepts, principles, theories and facts **are not schemas** and do not qualify as schemas until they are

organized into networks (i.e., **representations**) with stipulated relationships that are logically coherent and internally consisted to the degree that the state of knowledge in the area permits. The organizing and relating are key phases, stages and characteristics of learning and the learning process that typically must be explicitly attend to in instruction until the learner develops the meta-cognitive skills to do this for her or himself. Second, long-term semantic memory schemas are the basic stock and goals of “intellectual, academic, or subject-matter learning.” As such, these types of schemas are built, developed, shaped and weeded in stages which leads to instructions that focuses on the ‘weeding’ and “connecting” as much if not more than the explication of the “content of each of the elements’ in the schema. Just about every major cognitive psychologist since the Gestaltists have defined the fundamental unit of learning as being the “relationship” and thus the “proposition;” i.e., two concepts connected by a stipulated relations. All three elements must be explicitly taught to develop quality long-term semantic memory schemas. My last point is that again the expert and the novice have not brought the same functional stimulus into working memory for further processing and the are not processing their different functional stimuli with the same semantic long-term memory schemas which is going to produce vastly different processing results for each.

“Bubble” (long-term) memory is a relatively new type of long-term memory being recognized and explored in a variety of ways. 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). Traumatic information, therefore, is “there” in Bubble memory but it is disassociated with the other knowledge and interpretative memory systems and thus cannot be assimilated, accommodated, or rationalized which poses a number of processing and therapeutic problems. A milder form of “bubble memory’ is ‘flash bulb” memory (your personal memory of 9/11) and other milder forms are fears, phobia, and anxieties, which brings us back to the learning of scientific, mathematics, and other ‘difficult and charged” content. Understanding how such memories are formed, evoked and with what consequences as well as how they are stored and changed is undeniably important to the learning of science and mathematics and other difficult content and particularly under “high stakes” learning and performance conditions. There is also photographic long-term memory (perfect recall of verbal material) and eididic long-term memory (perfect recall of visual material) as well as aural memory. All of these are include here for completeness at this time but need further explication.

Working Memory

Working memory is both a confused and a controversial construct in many quarters. First introduced by cognitive and learning scientists and artificial intelligence theorists and researchers as relatively large and dynamic amounts of temporary but somewhat “long lasting” memory (as compare to short-term memory) needed to create and hold the interim and chronological products of iterative processing cycles and operations of the executive controller, programs and long-term memory on the transformed functional stimulus, it is now treated as something identical to short-term memory but my writer today both within and outside of mainstream learning and memory theory. Working memory is not the same thing as short-time memory and is very different for a widely variety of both logical and empirical reasons. The construct of working memory in my standard model is the construct of relatively large and dynamic amounts of temporary but somewhat long-lasting memory as outlined and explicated by Baddely (1986). No revised construct of short term-memory can account for or explain how one can remember and explicate very sizable amounts of “gist” of what one read, heard, or observed a week later but not a month later. Also, no revised construct of short-term memory can be made consonant with or

accommodate the spreading activation processes and mechanism both various models and the brain or parallel processing, which is now an established fact that can be simulated with groups of micro-processors. Both of these phenomena require relatively large and dynamic amounts of temporary but somewhat “long lasting” memory (for all of the reasons stated above) that are reasonably stable and enduring and that do not need to be constantly rehearsed and refreshed. Working memory is what Braddely (1986) and others say it is, and it is a logically necessary component of an information processing model of learning. Working memory has the “feeling of consciousness,” which short-term memory does not unless one has some very serious difficulties or is a very young child. Working memory is where the information that is streamed into it from short term memory (which is a buffer) is more highly analyzed, elaborated, and elaborated and enriched inferentially and deductively, and “felt,” and appraised and so on by the executive controller, various “programs” and the schemas stored in long and then transformed into products and responses (FS-4) that are sent to the response generator. Further explication of working memory is beyond the scope of this paper, as the component I want to explicate, which is relatively unexplicated in the literature, is the executive controller. Explicating the executive controller is one of the major contributions this paper has to make.

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 proto-science and fantastic science. It can model, explain and answer questions about how adult practicing scientists learn, make decisions (including ethical ones), work, conduct their business and retain or change their beliefs, and it can explain how student learn or do not learn science, the practice and conduct of science, make decisions (including ethical ones) and retain or change their beliefs.

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 glial 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 meta-cognitive 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. **One must always indicate the developmental level of model components when discussing, using, particularizing, or instantiating the model in a given context, as the model is significantly and qualitatively different at each developmental level.**

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 compiler has its 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 & Inhelder 1969) 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 my 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. The response generator is an important component of a standard model because it emphasizes and makes explicit Chomsky very important **competence/performance distinctions** relative to "knowing and understanding" and "doing" and "acting." I may understand if a sentence is grammatical or not, but I might not be able to write grammatical sentences because I have not yet develop the appropriate 'responding or response repertoire.' The "knowing how" or procedural component and knowledge of my understanding of grammar is not sufficiently developed for me to express my knowledge of grammar in original generative productions of my own. This response repertoire and generative capability is something that must be actively developed by me to express my understandings and knowledge. In general, performance lags competence and lack of performance does not necessarily me lack of competence. All of these points have many testing and assessment as well as teaching implications. These are but a few of the reasons why a response generator component should be included in any standard information processing model of learning.

Conclusions

One of the goals of this paper was to outline and briefly explicate an initial version a Standard Information Processing (Cognitive) Model of learning and learning processes based on an analysis of the models proposed and literature in this area for the past 25 years. One of the reasons for pursuing this goal was that when a major paradigm shift is occurring or has occurred in an area, there tends to be a large number of new, competing, and most often partial models generated by the "new view" of "old" phenomena. The over-generation of limited proto-models and their

rapid parallel and usually chaotic development often leads to several major problems that cause great confusions of many kinds, particularly if there has been no formal and explicit “weeding” function regularly applied to the process, which in turn stagnates the new emerging paradigm and causes paradigm and theory development blight. The secondary and tertiary effects in education and educational research of this chaos in the primary disciplines is even greater than the problems created in the primary disciplines which is a problem and an effect that should be an important concern of every in both the primary, secondary and tertiary communities, particularly as it is often very hard to unravel or correct in the latter communities.

One strategy for preventing emerging paradigm (and developing theory) “blight,” is to have professionals in an area develop and employ a **Standard Model** of the phenomena in question (Hawkins, 1991), which has a regularly occurring and very strong formal and explicit weeding function and mechanism. The development and use of such standards models in physics, genetics, archeology, and cosmology have been very productive over the past fifty years and have brought about much progress, clarity and coherent organization of both knowledge and inquiry. It is, without doubt, a proven approach to both preventing and solving a wide variety of problems in complex and rapidly emerging and changing areas of human knowledge.

One of the major advantages of having a standard model is that one can explicitly describe and characterize one’s own view or any given view relative to it in detail, which not only clarifies the view and its similarities and difference to the standard model, but also allows more precise, efficient, and highly productive communications and evaluations of all kind to occur, and for all views to be weeded, updated, improved and hopefully advanced. Explicit formal representations are one of the hallmark of no longer being “pre-paradigmatic.”

As both Kuhn (1965) and Eisenhart and DeHann (2005) point out, standard models and ‘weeded’ paradigms characterize the “hard sciences” and allow long and productive period of “normal science” to occur, but that both do not characterize the social sciences, or their “derivative discipline” education, which tend to be constantly “pre-paradigmatic” (i.e., immature) and characterized by endless controversies over (alleged) fundamentals and the hegemony of (allegedly completing) partial proto-models, theories and views, many of which are fossils in the knowledge development record. This characterization has tended to be true of the general and primary areas of learning theory over the past forty years and learning theories as translated, characterized and represented secondarily in various educational areas where many errors have crept into the representations and much has been lost in the translations creating many difficulties and problems that a standard models approach would help to correct and alleviate in the future.

Consequently, one goal of this paper was to establish the need for a standard and inclusive model of learning, and a standard model focus and movement in the social sciences, education, and science education in particular, and to describe what happens when there is not a standard model of learning available or orientation to such an approach over a forty year period. I hope that my description and analysis of excess individualism and the shotgun and indiscriminate borrowings that have occurred without regard to time, model or theory version, or principles, constructs and tenants and their completeness and coherence sufficiently characterize many of the salient characteristics

and current critical problems in the fields of learning, instruction and education today to convince the reader of the absolute need to develop and adopt an explicit standard and information processing model of learning, but particularly so in the area of science education, which is now so dominated by “trailing” (as opposed to “leading edge”) reduced marginal variants of a variety of (proto) theories, models, and views from “the cognitive revolution.” What really needs to be explained in science education over the past 30 years is how the mainstream cognitive revolution and numerous advances described in this paper were so badly and widely missed leaving the discipline left mired in a backwater of in a backwater of antiquated and extremely inadequate learning theories such as Gagne’s, Ausubel’s, Novack’s and Von Glaserfeld’s. But that is next year’s paper. Outlining an initial Standard Information Processing Model, therefore, should provide a stimulus and first step hopefully towards professionals in psychology and education, or at least science education, developing and adopting a consensus standard model of some kind if not mine, and in this respect I hope I have been successful in stimulating this process and outcome.

Lastly, shotgun borrowing and shotgun fishing expeditions also characterize a great deal of the “qualitative” research that has been done in education and science education in the last fifteen years. Shotgun empiricism is whatever form it takes and manifests itself, and it is time that education and science education in particular returned to theory driven controlled inquiry that is replicable and comparable and utilizes appropriate measurement and falsification principles in well-designed a priori activities (i.e., to science and scholarship). The standard information processing model presented here is as appropriate to qualitative and clinical research activities as to quantitative and experimental research activities and provides a standard and common core theoretical model for both approaches.