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Towards a Psychology of Science, Scientific Knowledge, and Scientific Change, Mark I.

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There is no first author or second author to this work. We both are first authors as this work is a truly interdisciplinary work to which both authors contributed equally.

ABSTRACT

This article attempts the ambitious, difficult, but necessary task of outlining in rough form a psychology of science. Although a small number of scholars and researchers are currently developing psychologically based accounts of science and scientific progress and change, these ideas are scattered across the science studies literature with no overarching framework, model, list of tenets, assumptions or postulates to systematically guide future work in this highly complex area of study. Under the key assumption that science is fundamentally a particular kind and type of cognitive (information processing) activity, this article (1) identifies 10 key propositions of a psychology of science and (2) highlights a standard information processing model that is capable of providing a conceptual system that can represent the wide range of epistemic, philosophic and sociological theses related to the nature of science and scientific knowledge. Although the ideas advanced in this article are in need of further synthesis, they open the door to numerous lines of inquiry related to a psychological approach to studying science and scientific decision-making as done by practicing scientists. At a minimum, this article highlights a number of important cognitive issues, concepts, questions and concerns that need to be addressed in any rigorous psychological study or account of the scientific enterprise. To ignore such cognitive issues today, based on the magnitude and quality of research in the cognitive sciences, is clearly both intellectually disingenuous and unscientific in spirit and impedes various kinds of scientific progress and acts of discovery, as well as practicing scientists being away of these dimensions of their work and decision-making. The implications of a psychological approach to studying the nature of science on science education and science literacy are also discussed.

Keywords: *Psychology of Science, Nature of Science, Nature of Scientific Change, Scientific Cognition, Scientific Decision-Making, Scientists as Learners, Integrating Disciplines.*

1. INTRODUCTION

Thargard (1988) and others (e.g., Giere, 1998; and Loose, 2004) have speculated that to understand science truly in a deep and nuanced way, a new discipline (or perhaps more accurately an inter-discipline) is needed. Obviously, and with little doubt, conceiving of and creating a new discipline is most certainly a risky endeavor, and one that requires some justification and clarification. Consequently, we will begin with a bit of both. It is important to distinguish between a "psychology of science" and the "science of psychology" (as well as the "psychological sciences"). In this regard, the ordering of the objects and prepositions are critically important to how these phrases are interpreted. Prepositions generally introduce and define the object of a sentence or phrase and indicate the logical relationship of its object to the rest of the sentence or phrase. Prepositions, therefore, define the semantic (meaning) component of the phrase. In the phrase "the psychology of science," the object is science, particularly a study of the behaviors of scientist and groups of scientists, as they go about doing the business of science, learning, experimenting, and

making scientific choices and decisions, as well as decisions about scientific matters and the work of other scientists. In the phrase "the science of psychology," the object is psychology, particularly the ways in which the field of psychology is scientific (e.g., systematic, experimental, testable, falsifiable, theory-based). Although advances in the science of psychology and the

psychological sciences are key to a modern psychology of science, it is important to remember that a psychology of science has as its ultimate aim a better understanding of science, scientific knowledge, change, and progress and not necessarily a better understanding of psychology (although bi-directional advance and progress is not only possible, but highly probable).

Although the psychology of science is not a formal, well defined and sustained field of study like the sociology of science pioneered by Robert Merton (1996) over 70 years ago, or the philosophy of science as explicated by logical positivists around that same time, there have been some very good attempts to explore and explain the psychological (cognitive) dimensions and aspects of science, as well as the fields of mathematics and logic. For example, the physicist-philosopher Giere (1988) attempts the ambitious task of synthesizing a unified cognitive theory of science that addresses shortcomings in philosophical and sociological accounts of science. As Giere points out, "Science is a cognitive activity, which is to say it is concerned with the generation of knowledge. Indeed, science is now the major paradigm of a knowledge-producing enterprise" (p. 1). Although we certainly agree that science is a cognitive activity and the major knowledge producing paradigm of our time, we believe it is more accurate and

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clearer to say that science is a very particular kind and type of information processing activity. This basic and very observable fact is the key principle and tenet of a psychology of science.

Yet, as Giere explains, modern philosophers of science have focused almost exclusively on the concept of rationality in science (and failed to consider the irrationalities of science), while sociologists look toward a purely social account of science and ignore the non-social aspects of science. By rigidly focusing on the core concepts that define their respective fields of study (i.e., rationality and sociality), both the philosophy and sociology of science have failed to develop a true and robust account of science, scientific knowledge, and scientific change. Indeed, Giere argues that “Having fewer (or at least less focused) disciplinary commitments, a cognitive theory of science is freer to be true to its subject” (Giere, 1988, p.5). Nevertheless, the key and important question to ask, it should be stressed, is “whose cognitive theory,” as different versions of cognition and ‘cognitive theory” abound, especially in psychology and educational disciplines and endeavors and in psychological and educational research models and methodologies (see Carifio, 2005 for details). We will, however, attempt to answer this question as we proceed with this discussion, and the development and explication of the thinking of the key scholars and theorists on this question and the topic of what a psychology of science would look like and be in general.

Based on advances in the cognitive, computer and information processing sciences, more contemporary scholars such as Giere and others are looking to model, describe and explain the nature of science by loosening or “fuzzifying” the philosophical requirements of epistemological justification and incorporating more psychological principles into these requirements. Using both psychology and philosophy to understand the nature of knowledge is referred to in historical terms as psychologism. Psychologism is the epistemological view and position that knowledge is best understood through studying the cognitive structures and mechanisms that create and judge its acceptability, a view that can be traced back to Locke. Psychologism is an important concept to understand, and it needs to be understood to appreciate the need for a modern psychology of science, scientific knowledge and scientific change. The main thesis of psychologism incorporates the prescriptive aims and practices of philosophy and logic (i.e., the types of inferences people should make) with the descriptive aims and practices of psychology (i.e., the types of inferences people do make) in developing the most comprehensive and realistic views and models of knowledge, and in particular scientific knowledge.

Although psychologism provided an interdisciplinary approach and model to studying the nature of scientific (theoretical) knowledge, psychologism was rejected by Western philosophers such as Frege in favor of antipsychologism. Antipsychologism, championed by the likes of Husserl, Popper and Frege, argued that philosophy and psychology should be kept separate and not combined or intermingled in the study of epistemology, for fear that the more descriptive (and less rigorous) claims and methods of psychology would dilute the formal logical rigor that defined 20th century Western philosophy (Thagard, 1988). One of the major problems with accepting the descriptive epistemology of psychology, as argued by philosophers, was that it opened the door to relativism (the idea that all knowledge is relative and can change from person to person with no objective standard). However, as is discussed below, some forms of psychologism avoid this criticism.

It is important to point out that that there are different degrees or types of psychologism, and that mapping the different versions of psychologism may be useful in understanding why psychologism is not prevalent in certain areas of education and instruction (particularly NOS studies) and how this issue can be effectively addressed. The most useful, but implicit, model and description of the different versions of psychologism is offered by Thagard (1988) who uses Artificial Intelligence procedures to develop computational models of scientific thinking. Based on the work of Haack, Thagard defines three types of psychologism: weak psychologism, strong psychologism, and antipsychologism. Weak psychologism is the view that “logic is prescriptive of mental processes” (Thagard, p.7), which is a view consistent with Piaget’s genetic epistemology. Strong psychologism “is the view that logic is descriptive as well as prescriptive” (Thagard, p. 7). Antipsychologism is the view that “logic has nothing to do with mental processes” (Thagard, p. 7).

Thagard and many others have argued and implied that a weak version of psychologism is the epistemic framework of greatest potential because (1) it is a less extreme epistemology (compared to the strong and antipsychologism positions), and (2) it maximizes the epistemic gains that result from interdisciplinary research (such as exposure to a wider and different repertoire of concepts, theories and views), while avoiding the charge of relativism. Table 1 provides a profile for each version of psychologism outlined by Thagard.

Table 1: Profiles for the three different versions of psychologism.

	Logic of “Mental” Processes		
	Descriptive	Prescriptive	Escapes relativism
Weak	Somewhat	Somewhat	Yes
Strong	Yes	Yes	No
Anti	N/A*	N/A*	Yes

*antipsychologism argues that logic has nothing to do with mental processes,
hence the descriptive and prescriptive categories are moot and not applicable.

The two main benefits of weak psychologism outlined by Thagard and suggested by Giere and others provides the framework for a psychology of science and a truly interdisciplinary approach to a study of the nature of scientific knowledge and scientific change. Considering the incredible rate and magnitude at which knowledge is growing presently in all areas of cognitive science and research, it is hard to imagine that a meaningful study and realistic account of the nature of science would not be (1) psychologically based, (2) highly interdisciplinary, and (3) adopt psychologism as its guiding epistemology. This model of the psychology of science applies equally well to nature of science (NOS) instruction and the goal of a scientifically literate population, as the current standard of NOS instruction tends toward antipsychologism (see Perla and Carifio, 2011).

The problem with adopting a weak version of psychologism exclusively is that it may not be the most effective epistemology for all aspects of a psychology of science. In the process of developing a discipline or program such as a psychology of science that is scientifically based, one is likely to encounter problems, issues, concepts and questions that require approaches consistent with antipsychologism (e.g., pure logic, such as the transitivity postulate), psychologism (such as theory creation) and all points in between (which is the case in modern cognitive science and especially neuroscience and brain and memory research (see Ashcraft, 2002). Considering that researchers like Thagard and Giere received professional training in philosophy, their adoption of a "weak" version of psychologism is likely to be an attempt not to offend traditional philosophers and logicians. However, as is described below, a modern psychology of science has no particular commitment to any version of psychologism and feels free to apply the epistemic strategy best suited to address the problems it will encounter. We refer to this dynamic interdisciplinary strategy as a shifting epistemological scale or toolbox, and this "sliding scale" is what we believe Giere is referring to when he states that a cognitive theory of science is freer to be true to its subject.

It should be pointed out that the cognitive virtues and advantages of psychologism were advanced in nascent form by scholars such as Fleck (1935), Bachelard (1935) and, perhaps most notably, Kuhn (1962). Each of these scholars recognized, like Giere, that science is (1) a cognitive activity and (2) the most important and substantial paradigm for knowledge production. However, both Fleck and Kuhn (and others) recognized that at the time they were developing their theses, the existing cognitive knowledge base was in its infancy and that our understanding of cognition would be the limiting factor relative to our understanding of the nature of science. Today, the cognitive sciences and related fields provide much information that can be effectively synthesized and mobilized to create a psychology of science like that envisioned and anticipated by Fleck and Kuhn. Accordingly, this article begins the ambitious task of providing a general framework and initial standard model for a Psychology of Science, a discipline that has the potential to substantially inform our understanding of science and impact science education, especially as it relates to the NOS instruction and science literacy. A general (standard) model and synthesis of the key and defining characteristics of a modern psychology of science is greatly needed, as much of the work advanced in this area to date, although quite good, is scattered across different disciplines and does not appear to be sustained in the academic or instructional main stream literature.

The purpose of the remainder of this article, therefore, is to outline a general "psychology of science" and its key functional elements, commitments and assumptions that are based on the standard integrated information processing (cognitive) model of learning developed by Carifio (1993, 2005). As researchers and scholars begin to more seriously explore the psychology of science, and as our understanding of basic cognitive and emotive functioning develops, the greater the need becomes for a standard model and approach to study the psychological aspects and dimensions of science. The development and use of standard models in physics, chemistry, genetics, archeology, and cosmology have been very productive over the past 50 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.

2. STANDARD MODELS

As stated earlier, a psychology of science has as its ultimate aim a better understanding of science, scientific knowledge, change and progress. From a philosophical perspective, there have been numerous individual models and "theories" of the nature of science and scientific progress developed over the past century, with most authors agreeing that science does indeed progress (although the specific criteria of progress may differ between authors). Most of these philosophical models of scientific progress and change fall into two general categories: (Type 1) scientific progress as incorporation and (Type 2) scientific progress as revolutionary overthrow of current "normal science" (see Losee, 2004). This simple distinction between different commitments and models of scientific change and progress, although helpful, does not equate to anything close to a standard model, and most modern philosophers of science would surely raise numerous objections to the idea of a standard model of scientific progress (perhaps from fear of unemployment). Type 1 and Type 2 varieties of change and progress are fundamentally

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different, much the same way the cognitive concepts of assimilation and accommodation are different. The question really is not which philosophical model or view is correct, as proponents of both Type 1 and Type 2 views have made strong cases for their positions over time. The question is what type of model (or discipline) is best suited and most capable of representing each of these different established philosophical views of scientific change and progress and of newer views that are emerging.

Accepting the assumption of Giere, Thagard and numerous other main stream philosophers and cognitivists that science is a cognitive (information processing) activity, we believe that a modern (cognitive) psychology of science is the only discipline or intellectual endeavor that can represent diametrically opposed philosophical views in one coherent (but not perfect or complete) model. In other words, a standard model of science must be psychologically framed and cannot be philosophically or sociologically framed because of the limitations that exist that define traditional philosophy and sociology of science as discussed by Giere above. These latter fields (philosophy and sociology) are, in many respects, too specialized to provide the type of general framework for the complex cognitive behaviors and interdisciplinary alliances that define science, technology and society today. Indeed, models of limited and restricted scope make poor general and standard models (Kerlinger & Lee, 2000). In our model of scientific progress, different philosophical and sociological views and models are the micro models that are subsumed by the psychological (cognitive) macro model. As ideas are incorporated into the psychological macro model it becomes easier to see the larger picture that emerges and to identity conceptual anomalies, or views and theories that are on the fringe of established scientific thought.

For example, the two different and antithetical philosophical and concept models of scientific change and progress (the slow, accretive and local view of small units of change and progress versus the sudden, dynamic, and sweeping, global revolutionary change and progress) may be both reconciled and integrated into one general macro model using the gestalt psychologists principles in insight and sudden perceptual shifts that completely reorganize views, schemas and theories that only occur under a very specific and short-term set of conditions. In fact, using nonlinear dynamics and Thom's (1975) cusp catastrophe model of sudden change, we have model Kuhn's theory of "scientific revolutions" and how and why they occur during the course of the pursuit of normal science from a psychological view of scientists' information processing of their own work and experiments as well as those of other scientists (see Perla and Carifio, 2005b for details). This psychological model of scientific change may not only be used to better understand, model and guide the behaviors and understandings of practicing scientists about the scientific change process, which is actually developing their meta-cognitive skills and understandings, but it may also be used to better teach students and scientists in training about the very same things and quite explicitly and precisely. Many similar specific examples can be cited and will be cited below. Such explicit, dynamic and mathematically models of science or scientific change are not developed by philosophical or sociological views of science, or its nature, conduct and change process, which is our central and key point here that underscores why developing a psychology of science is so important and needed.

As previously stated, a 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 50 years to the point where each is currently experiencing a "mini-renaissance" of some kind (see Penrose, 1991).

The standard model approach has (to the best of our knowledge) never been an approach employed in philosophy or any of the social sciences, but most particularly in psychology, including cognitive psychology as well as opposed to the cognitive sciences. 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 differences to the standard model, but also allows more precise, efficient and highly productive communications and evaluations of all kind to occur, and for all view to be "weeded," updated, improved and hopefully advanced (see Carifio and Perla, 2009 for both an example of and details on this point). This type of standard model approach is absolutely necessary to define a psychology of science considering (1) the major advances made in the cognitive sciences and related fields over the past half century, and (2) the wide range of interdisciplinary fields and findings that now inform our understanding of scientific knowledge, change and progress.

3. PSYCHOLOGY OF SCİENCE: A STANDARD MODEL APPROACH

This article has suggested that any field of study or discipline, such as the psychology of science, relies on key assumptions and perspectives and a standard model that can instantiate these key assumptions and perspectives. In this section of this article, 10 key assumptions and views underlying a modern psychology of science are described, followed by an outline of an integrative information processing model that is capable of instantiating these 10 key assumptions. The 10 key assumptions listed below are not an all inclusive list of assumptions relative to a Psychology of Science; rather they provide an idea of the qualitative types of ideas and concepts that are needed to fully develop a psychology of science.

a. Key Assumptions That Define a Modern Psychology of Science

i. At the most fundamental ("molecular") level, science is a very particular kind and type of information processing activity (see Perla and Carifio, 2009 for details);
ii. All viable information processing models have an explicit theory of the responder; in a psychology of science, the primary responders are scientists or groups of scientists.
iii. The information processing that occurs in science is an attempt to create reliable, valid, testable and sound knowledge about the world; that is, an attempt to actively engage in learning behaviors of various kinds (by definition) in order to create (to some degree new) knowledge as that knowledge does not currently exist (in sufficiently close to finished form). To both conceive and characterize practicing scientists as continual life-long learners (and perpetual pioneers) not only produces jarring cognitive dissonance for many philosophers, sociologists, science educators and others, but is usually a concept and conceptualization that is buried at the bottom of their (implicit) schemas and concept maps of the nature of science rather than as a higher order node, which at one level is the crux of the problem. Accommodative re-conceptualizations are both highly needed and most definitely in order, and not only on this particular point and issue.
iv. A comprehensive understanding and appreciation of science today requires an interdisciplinary approach that includes disciplines such as the cognitive sciences, philosophy, history, sociology, mathematics, computer science, logic, linguistics, and the primary scientific disciplines (e.g., physics, biology, chemistry);
v. Cognitive psychology can provide an overarching and subsumptive (macro) framework for a meaningful understanding of scientific knowledge, progress and change;
vi. Much of what we know about the nature, abilities, scope and limitations of human thinking comes from very detailed and multidisciplinary analyses of the history of science as well as fundamental and continuing advances in the broad array of basic and psychological sciences;
vii. Scientific thinking is not easy to understand because scientists (like everyone) are not always completely logical and are influenced by society, personal motivations, delusions, and insecurities and similar factors and scientists, like everyone else are only partially knowledgeable and intermittently rational (the question being how partial and how intermittent).
viii. Some of the most important and influential writings in the philosophy and sociology of science (such as Fleck, Bachelard, Quine, Merton, Black, Whewell, Kuhn, Lakatos, Masterman, Feyerabend, Popper, and many others) implicitly or tacitly center on psychological assumptions, concepts, views and principles;
ix. Science employs both formal logical mental operations as well as metaphoric and creative (less logical) mental operations such as intuition, dreams and insights (see Carifio and Perla, 2005a for details). Formal logical operations are associated with the context of epistemological justification, while metaphoric operations are associated with the context of discovery.
x. A psychology of science is free to employ shifting epistemic preferences and standards based on the problems it encounters (i.e., different degrees of psychologism).

Although each of these 10 points is important in its own right, the idea that science is a particular kind and type of information processing activity (point #1) is the most important and critical to a modern psychology of science. As point #6 notes, most, if not all, of the classic works in the philosophy and sociology of science make very strong psychological arguments in the process of developing their key ideas. Further, virtually every one of the classical philosophical and sociological arguments centers on how information in the sciences is processed and what decisions and behaviors result from this information processing activity. From Whewell to Popper to Kuhn to Feyerabend and all points in between, most models of scientific knowledge focus on the criteria (logical or illogical) used to accept, reject or modify a scientific theory, view, idea, proposition or hypothesis. Historians, philosophers and sociologists of science recognize that science is a way of processing observations made in the natural world into a coherent system of concepts and relationships that overcomes our tendency to draw quick and often false and distorted conclusions that lead to specific behaviors—and this is exactly the intent of developing and understanding information processing models. Science is about information processing, and each historian, philosopher and sociologist of science—regardless of how different their views or perspectives may seem to be—has developed a fundamentally psychological thesis on the behaviors of scientists and most particularly so relative to how scientists process information when they are doing science or evaluating the science done by others. Nevertheless, psychology and psychological principles and advances have been a background or "nuisance factor" in many, but not all, of the key classical works in the history, philosophy and sociology of science (i.e., an instantiation of antipsychologism). A psychology of science requires a conceptual transformation or

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revolution that not only embraces strong psychologism (at times), but one that also places psychology at the center of nature of science studies (and not on the conceptual or intellectual periphery). This type of transformation is what largely defines a modern psychology of science.

Because information processing models are key to understanding the nature of science, scientific change and scientific progress, an explicit information processing model is a requirement for a modern psychology of science. Below is an overview of the basic principles and sub-components of a comprehensive, integrative and standard information processing model and theory of learning developed by Carifio (1993, 2005) that is based on the standard models in physics and is ideally suited to model all aspects of information processing in the sciences. Although a detailed description and diagrammatic version of Carifio's model is available elsewhere (see Carifio, 1993, 2005), the five points below highlight the key features of the model. It should be stressed that each aspect and feature of Carifio's model has been substantiated to different degrees vis-à-vis the history and philosophy of science literature. The model, therefore, serves as an ideal standard psychological model, template or mapping of the cognitive factors that influence the behaviors of information processing in science and opens the door to a new formal and explicit field of study: The Psychology of Science.

b. Standard Information Processing Model: Key Features

i. Cognitive Limits:

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

ii. Partial Rationality:

- Any given person is only partially knowledgeable about anything and most things (almost always), which is a basic fact that has many and many profound implication and consequences when the variables of points in time and degrees of partiality are introduced into this core point and the work scientists do and the believes they have before and after key new knowledge discoveries.
- 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. It is also well documented in science as a corollary to this that that intermittent periods of "stronger than usual irrationality" often foster creativity and important discoveries when the constraints of logic and rationality are loosened somewhat and metaphoric operativity is allowed to flourish more (see Perla and Carifio, 2005a).
- There are, however, degrees of partiality (of knowledge and rationality) and the frequency and length of these intermittent periods and activities which are key to understanding processes, development and scientific as well as personal change over time.

iii. Schemas:

- 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).

iv. Parallel Processing:

- There is not a "single" process or "processing" at any given moment in a processing system, but rather a multiplicity of different processes and processings going on that are loosely and fuzzily coordinated and interconnected with many tests, checks and balances, information exchanges, error corrections and redundancies very similar to Selfridge's (1959) original Pandemonium Model of cognitive processes and organizations. Processes occur in recurring mico-cycles, which operate by and bring about spreading activation, which may be deep or shallow.

v. Executive Families:

- There is not one executive processor, or central processing unit or type of central processing unit, which is the view of the classic model and the preponderance of theories in this area, but rather a family of (qualitatively different) executive processors which are loosely coupled and work in parallel and communicate with each other through fuzzy channels somewhat like the two hemispheres of the brain and the corpus collosum.
- Each of these executive processors in a person's family of executive processors is a generative specialized compiler with its own representational system, language, logic and set

of functions and commands which goes through development level and customization (Cattell's [1963] crystallization) over time through interactions with the outer and inner environment (Minksy, 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).

It should be stressed that each of these basic key features of information processing as outlined in Carifio's model can be recovered from and mapped to historical examples of scientific development, change and progress (see Perla & Carifio, 2005 for details). It should also be point out that all information processing like all science is about decision-making under conditions of uncertainty, which is exactly what a psychology of science is all about in terms of modeling, understanding, explaining and predicting relative to the many and diverse behaviors of scientists.

An example of this point, the detailed and insightful writings of Polya in his classic book How to Solve It (see Carifio and Allen, 2005 for details), and the same with Randy Rucker in his classic book Mind Tools and, of course, the writings of Fleck (1935), Kuhn (1962) and many other about the process and psychology of doing and understanding science and scientific change. Lastly, the model we have provided above for a psychology of science would also apply to a psychology of mathematics as is quite clear from the writings of Polya and others (see Perla and Carifio, 2005 for details).

4. CONCLUSİON

This article attempted the somewhat ambitious and difficult but necessary task of outlining in rough form a psychology of science. Although a small number of scholars and researchers are currently developing psychologically based accounts of science and scientific progress and change, these ideas are scattered across the science studies literature with no overarching framework, model or list of tenets, assumptions or postulates. Under the key assumption that science is fundamentally a particular kind and type of cognitive (information processing) activity that involves various kinds decision-making under conditions of uncertainty, this article highlighted a standard information processing model that is capable of providing a conceptual system that can represent the wide range of epistemic, philosophic and sociological theses related to the nature of science and scientific knowledge, and particularly so from a psychological and process perspective. Although the ideas advanced in this article are in need of further synthesis, they open the door to numerous lines of inquiry related to a psychological approach to studying science. At a minimum, this article highlights a number of important cognitive issues, concepts, questions and concerns that need to be addressed in any psychological study of the scientific enterprise. To ignore such cognitive issues today based on the magnitude and quality of research in the cognitive sciences is intellectually disingenuous unscientific in spirit.

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