# Theory Creation, Modification, and Testing: An Information-Processing Model and Theory of the Anticipated and Unanticipated Consequences of Research and Development

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**Background:** Extending Merton's (1936) work on the consequences of purposive social action, the model, theory and taxonomy outlined here incorporates and formalizes both anticipated and unanticipated research findings in a unified theoretical framework. The model of anticipated research findings was developed initially by Carifio (1975, 1977) and was followed by the addition of the unanticipated findings component by Perla (2006). This is the first formal model, theory and synthesis of anticipated and unanticipated research findings developed to date. The wide-ranging consequences and implications of the model are discussed.

**Purpose:** To the extent that educational researchers, philosophers and scholars reduce unanticipated findings solely to chance, whimsy, or inspiration they declare these occurrences impossible to effectively predict, model or understand. This article provides a way to conceptualize and formally model anticipated and unanticipated research findings. Many concrete examples from the history of science and research and evaluation methodology are provided to illustrate the model as well as various details of an application of the model in developing instructional materials.

**Setting:** Nature of science instructional materials development effort.

**Intervention:** Not applicable.

**Research Design:** Theory and model development using quantitative and qualitative methods including literature review and original model evaluations.

**Data Collection and Analysis:** Content analysis and modified Q-sorts of research related documents, journals, logs, literature and emails as well as various theory construction and modification techniques.

**Findings:** This article demonstrates that a formal model and theory of anticipated and unanticipated research findings can be developed and that such models should inform a broad range of research and evaluation efforts that are conducted daily worldwide. Nine key research and evaluation principles were derived to supplement the formal model and its operations that should be helpful to novice as well as experienced researchers regardless of the research methodology or strategies they are employing.

**Keywords:** theory construction; discovery; research methodology; information processing; program evaluation; serendipity; nature of science; instructional materials

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In his now classic article *The Unanticipated Consequences of Purposive Social Action*, Robert Merton (1936) provides a rough conceptual and epistemic framework for the systematic analysis and treatment of one of the least understood phenomena in all areas of inquiry (and research): findings and outcomes of varying degree and magnitude that are unexpected by the individual (or researcher) prior to the execution of some type of purposive action. Being a scientific scholar and sociologist of science, Merton was never at a loss to provide examples of how unanticipated findings in the natural sciences contributed equally, if not more so, to shaping and advancing our collective understanding of natural phenomena vis-à-vis the more anticipated variety of experimental outcomes. Of course purposive social action (defined specifically below) goes beyond the activities of the physical and natural sciences and can be, as Merton pointed out, applied to a number of different social actions, behaviors, situations and institutions—which would include education and educational research and evaluation. For instance, the classic studies on memory and learning by Ebbinghaus (1885/1965) that eventually, and quite unpredictably, led to the learning (or forgetting) curve and which provided the foundation for modern experimental psychology are an instantiation of the elements of the unanticipated consequences of purposive social action outlined by Merton. Similarly E. L. Thorndike used unexpected findings from his failed studies on mind reading in children to formulate the initial version of the Law of Effect (1905) which he developed more fully over the subsequent decade.

More recently, Gene Glass' discovery of meta-analysis that resulted from his attempt to make sense of the opposing and contradictory research findings of psychoanalysis could also be framed in a Mertonian unanticipated consequence framework (see Glass, 2000)—a discovery that has had a profound influence in research both in the "hard" and "soft" sciences.

Despite the fact that unexpected findings probably outnumber expected findings in any research endeavor by a significant margin (if they were to be tallied) and the fact these findings may represent the conceptual vehicle for important gains in different fields of study, as they have in science, they have not received the attention and *formal* elaboration they deserve in the social sciences, education and educational research. One of the goals of this article is to incorporate Merton's views on unanticipated findings into the more traditional and classic models of research, development and evaluation. The result of this synthesis is a more comprehensive research and evaluation model that incorporates both the "context of justification" and the "context of discovery" (Reichenbach, 1938) leading to a better understanding of theory development, evaluation and revision.

## Merton, Unanticipated Findings and Theory Development

To the extent that educational researchers, philosophers and scholars reduce unanticipated findings *solely* to chance, whimsy, flashes of brilliance, divine intervention, inspiration or "ah-ha" moments, they declare these occurrences impossible to effectively predict, model or understand as Merton discussed in detail in 1936 (p.894). Unfortunately, this analysis is as true today as it was 70 years ago, as there are scholars in all fields of study that adopt aspects of this view of unanticipated research findings that Merton so strongly criticized. Indeed, many extant forms of qualitative research in education (e.g., action research) that purport to create theory and let research themes emerge have largely ignored the fundamental epistemic issues related to unanticipated findings, despite the fact that such findings actually define the very purpose of their programs. Any research that employs a flexible and emerging design still requires a starting point (complete with axioms of choice) and a rough and fuzzy endpoint (even telling a story involves a beginning and anticipated end point, even if the end point changes over time). By definition, something that emerges (e.g., a theory or hypothesis) is not know before hand and therefore represents a form of unanticipated finding. This emergent view of research findings is situated along the "context of discovery" end of the research spectrum.

At the other end of the spectrum (i.e., the "context of justification" end), educational researchers over the past four decades advocating experimental and quantitative research designs have focused almost exclusively on rigorously conceptualizing, testing and substantiating (or falsifying) theories, ideas and views (e.g., Campbell & Stanley, 1963; Kerlinger & Lee, 2000), leaving them less open to the potential virtues of unanticipated findings, or to view such findings and experiences as problematic or as experimental background noise and beyond the scope of the ideas being tested. For example, Campbell and Stanley (1963) make the following assertion related to educational research: "If, as seems likely, the ecology of our science is one in which there are available many more wrong responses than correct ones, we may anticipate that most experiments will be disappointing." (p. 3). Assuming "wrong responses" are to some extent unanticipated and undesired, this quoted passage suggests clearly (and rather intuitively) that the probability of encountering an unanticipated outcome is quite good in research and that a systematic study of such findings would be fruitful. However, Campbell and Stanley also cast wrong responses in a negative, disappointing, and even physically painful frame, and researchers sharing this view may focus on what went wrong with the research before (if at all) assessing the value of the undesired finding. In contrast to this view, Merton (1936) points out that "undesired effects are not always undesirable effects" (p. 894).

This view of Merton's was also strongly held by J. T. Seery, head Naval of Research and Development, who noted that "The real skill, of course, lies in the ability to forgo the unpromising occurrence, however interesting it may be, and relentlessly pursue that which, found but unsought, may pay greatest dividends in progress," (As cited in Merton & Barber, 2004, p. 216). In other words, there are *decision points* along the research front, and especially long and involved research and evaluation projects, where decisions need to be made about which findings to pursue; namely, the anticipated or unanticipated findings (if they have both been allowed to enter the process). To the extent that highly organized research models make anticipated *and* unanticipated outcomes more readily observable by contrast, they not only increase the complexity of the research process, they also increase the probability that a researcher open to such findings will maximize their research efforts. This point is why the context of discovery as well as the context of justification components and frames need to be part of all research and evaluation models and designs explicitly, even if just to point out that one or the other is being minimized in a particular instance.

For example, researchers working in a Kuhnian paradigm and "normal science mode" and the intense focus and commitment it provides to some well-formed and partially pre-determined and anticipated end, may be blind to the value of the unanticipated finding (similar in some cases to what Kuhn [1996] called "anomalous" findings)—even if the unanticipated finding demonstrates more insight and promise than the anticipated finding. This type of conceptual rigidity is well described in the psychological literature and is similar to what has been termed *functional fixedness*, or the "tendency to use objects and concepts in the problem environment in only their customary and usual way" (Ashcraft, 2002, p. 497). As will be demonstrated with the model presented here shortly, one way to hedge one's research bet and understand the significance of findings that were found but not sought is to have general research models available where the theoretical frameworks are well articulated and address customary (anticipated) and uncustomary (unanticipated) findings. In the absence of such models, the value of an anomalous or unanticipated finding may be obfuscated, misunderstood and possibly over or underestimated.

Merton's early work emphasized that an understanding of unanticipated consequences of purposive social action, and its associated generalizations, was largely *context mediated*. "Before we may indulge in such generalizations, we must examine and classify the *types* of social action and organization with reference to the elements here discussed and then refer our generalizations to these essentially different types" (Merton, 1936, p. 904). Merton further noted that unanticipated consequences may be derived from both unorganized and organized action, but that organized action "would seem to afford a better opportunity for sociological analysis since the very process of formal organization ordinarily involves an explicit statement of purpose and procedure" (Merton, 1936, p. 896). Again, reflecting on unexpected discoveries made by those doing research on clothing and textiles for the Bureau of Supplies and Accounts, Seery notes that "these unexpected but profitable occurrences are almost always the byproducts of planned research and development" and that "the future depends to a considerable extent, not on happenstance alone, but skill in serendipity" (As cited in Merton & Barber, 2004, p. 216).

## Aim and Focus

To say that the type of formal classification and organization of unanticipated outcomes (and skill in serendipity) envisioned by Merton and Seery has not occurred in academic research would be an understatement. The aim of this article, therefore, is to introduce a formal model and theory of anticipated and unanticipated (educational) research findings in the context of an instructional materials development program that addresses, operationalizes and extends many of Merton's basic principles and concepts. This model is equally applicable to experimental treatments and various types of programs and tests beyond education and instructional materials development. A formal and well-articulated model of anticipated research findings is a significant achievement of its own and a necessary starting point for a coherent model of unanticipated findings. Echoing this fundamental point, Shapin (2004) points out that "You want to have a good enough idea of what you are looking for to be surprised when you find something else of value..." (p. 1). Of course recognizing something else of value involves a level and degree of cognitive and intellectual preparation, as Pasteur reminds us with his oft-cited maxim "chance favors the prepared mind."

The research model and theory outlined here incorporates and formalizes both anticipated and unanticipated findings in a cognitive theoretical framework, and its central assumption is that a general, formal and functional (generative) model of anticipated research findings is the best starting point for a model of unanticipated findings and that the two can be fused together creating a synergistic and comprehensive research model and theory (see below). The model of anticipated research findings was developed initially by Carifio (1975, 1977) and was followed by the addition of the unanticipated findings component by Perla (2006). Describing, the experiences and insights that led to this "fusion of models" is the main focus of this article.

In this work, purposive social action (see below for details) represents the collaborative activities of educational researchers engaged in developing high quality instructional materials. Further, the model and theory outlined in this article is not merely speculative; it represents the (unanticipated) outcome of one the most commonly recognized academic forms of purposive social action (i.e., development of instructional materials for students and teachers) (Perla, 2006). The next section of this article introduces nine key principles that guided the development of the research model.

## Nine Key Principles

Based on the brief analysis above, nine key principles can be derived and summarized as a guide to developing a model of unanticipated consequences of purposive social action, where purposive social action is defined specifically as academic research. Each of these nine principles is operationalized in the research model described in the next section of this article that focuses on a process of systematically developing, validating and evaluating instructional materials for post-secondary educators and educational researchers related to the nature of science.

### *Principle #1: Although Specific Unanticipated Findings Cannot be Predicted with Good Precision, we can Anticipate and Parameterize Where such Findings will Emerge During Research Activities*

It is important to emphasize that although we cannot anticipate that which is unanticipated, we can roughly parameterize and gauge— through general structured models—where unanticipated findings may emerge or materialize during the course of research and prepare accordingly. This assumption is central to the model and theory developed in this article and is a basic requirement of any effective model, theory or taxonomy of unanticipated consequences of research.

### *Principle #2: Human Beings have Cognitive Limitations*

Because human beings (and researchers) are limited information processors and only partially knowledgeable of any given field at any given time, unanticipated findings are a part of any and all research endeavors. Accepting the cognitive limits and deficits of human thought provides the logical justification for the argument that unanticipated findings can always be anticipated to some extent in research due to the imperfect ability of researchers to plan, conceptualize and execute their research.

### *Principle #3: Unanticipated Findings are the Product of Anticipated Findings*

Unanticipated consequences of research are derived from and made noticeable by anticipated consequences of research that provide the structure, starting point and necessary contrast to the unexpected.

### *Principle #4: In General, as the Level of Research Organization Increases so does the Probability of Identifying Unanticipated Findings*

Related to Principle #3, the more organized the research structure or plan, the greater the probability an unanticipated finding will be noticed (due to contrast), assuming the researcher is open to intellectualizing such findings (see Principle #7). Also, the more organized the research plan, the more difficult it becomes to make inappropriate, inaccurate, or disingenuous post facto associations relative to unanticipated findings.

### *Principle #5: Important Unanticipated Research Findings Involve Chance and Skill*

The ability of a researcher to identify an unanticipated finding (and ascribe some level of value to it) is based not only on a chance occurrence, but also on the level of preparation, skill and conceptual understanding of the researcher. In other words, the more the researcher knows about the processes under investigation (i.e., understanding of the knowledge bases in question), the greater the likelihood that an unanticipated finding could be recovered. This point is the basis for Louis Pasteur's maxim that "chance favors the prepared mind" and Seery's criteria for "*skill* in serendipity." Fleming's discovery of penicillin provides an example of the importance of both chance and skill in observation as does Thorndike's chance discovery of the effects of reinforcement in learning.

### *Principle #6: Research Models Should be Context Specific*

General models of unanticipated findings (as well as all research findings) should be context specific in order to maximize the understanding, application and generalization of such findings.

### *Principle #7: Researchers Should be Open to the Unexpected*

Researchers need to be open to intellectualizing (formalizing and theorizing) unanticipated findings and moving beyond the anticipated findings and structure of their research when there is indication that the unanticipated findings will produce the greatest insight and payoff. Unanticipated research findings, including extremely important findings, even within highly structured research programs (see Principle #4) may be ignored, trivialized, or reduced since human beings (especially researchers) tend to work within a specified theoretical structure and framework (Kuhn's paradigm and normal science). They also tend to demonstrate functional fixedness, and have no formal experiences with, or models of, unexpected research findings.

## *Principle #8: Research Models Should Address both the Context of Discovery and the Context of Justification*

Research that focuses exclusively on the context of justification (experimental falsification and/or verification) may tend to overlook an unanticipated finding if some of its related aspects have been falsified, whereas research that focuses exclusively on the context of discovery (focus on creativity, informal and exploratory analysis) may lack the criticalness needed to better formalize, understand and generalize unanticipated research findings, which are often viewed as discoveries (Reichenbach, 1938). As is demonstrated in the next section, models that include both contexts create the most comprehensive and realistic view of the research landscape and allow for better insight of the research process.

## *Principle #9: Research Models are a Specialized Form of Information Processing Models*

Many people do not explicitly think about or conceptualize a research model and experience (or other forms of purposive social behavior) as a form of information processing, but that it exactly what research is. Thinking about the research process and experience as a higher order and complex form of information processing provides much of the justification for the formalization of findings that are unexpected in the research setting, since all forms of human information processing and perception (including research-guided processing and perception) is highly dynamic and fallible.

These nine principles serve as a conceptual guidepost and framework that can be used to think about research models that include a serious consideration of what has long been accepted as an enigma of research and excluded from formal analysis—*the unanticipated finding*.

The model described in the next two sections of this article provides what is, to our knowledge, the first formal model of both anticipated and unanticipated research findings in a specific research context. This model, incomplete and exploratory as it may be, was developed during the development of instructional materials for undergraduate students and faculty related to the nature and epistemology of science (Perla, 2006). The model is introduced systematically in two parts. The first part of the model describes the framework that guided the anticipated outcome of the research (i.e., development of valid materials to be used in college classrooms). This model is referred to as the original model and it is a *context of justification* model. During the *execution* of the original model, a number of unanticipated findings were encountered that led to elaboration of the original model. The elaborated model incorporates the unanticipated findings into its structure and provides the *context of discovery* component, thereby making it a more comprehensive model and tool. The focus of this article is not the specific findings of the research per se, but to define the structure of the models developed and the points along the models paths where anticipated and unanticipated findings were identified. Specific examples from the research are used where appropriate to aid understanding of the different components of the models.

## A Formal and Explicit Model of Anticipated Research Findings

The development of instructional text and materials is in most instances a highly noisy and fuzzy process and endeavor, and this is one of the problems this research, specifically the original model, addresses. The question was can this process be otherwise and reproducibly so and to what extent and with what consequences. The original model, first developed by Carifio (1977), has demonstrated it is capable of logically guiding the development and validation of various subject-specific instructional text and materials, and similar results were achieved for the present research (see Perla 2006 for details). The original model may be used for just about any content or construct (e.g., self-concept, reading, attention, educational equity) and for conducting most kinds of experiments or inquiries (e.g., healthcare, social policy, technologies, agriculture and so on).

As can be seen in Figure 1, there are macro and micro frameworks and theories in the original model. The *macro instructional framework* begins with a data mining theory, process and model by which the relevant scholarly and non-scholarly literature for an area, topic or discipline is established, screened, weeded and refined into a *Critical and High Quality Knowledge Base* (CHQKB). Figure 2 depicts in detail the CHQKB for the Nature of Science (NOS) domain identified in this research. The CHQKB is derived from four primary sources including a review of (a) the science education literature, (b) primary sources in the history and philosophy of science, (c) materials from leading history and philosophy of science centers, institutes universities and groups, and (d) science education standards documents in the United States. The CHQKB is then translated into *Appropriate Representations and Communications* (ARCs) for a particular audience or set of audiences, which are then *Validated and Field-Tested for Effectiveness* (VFTE). What constitutes appropriate and high quality instructional materials and their testing are the micro theories in this macro model framework and the relationships between these macro models are depicted visually in Figures 1 and 3.

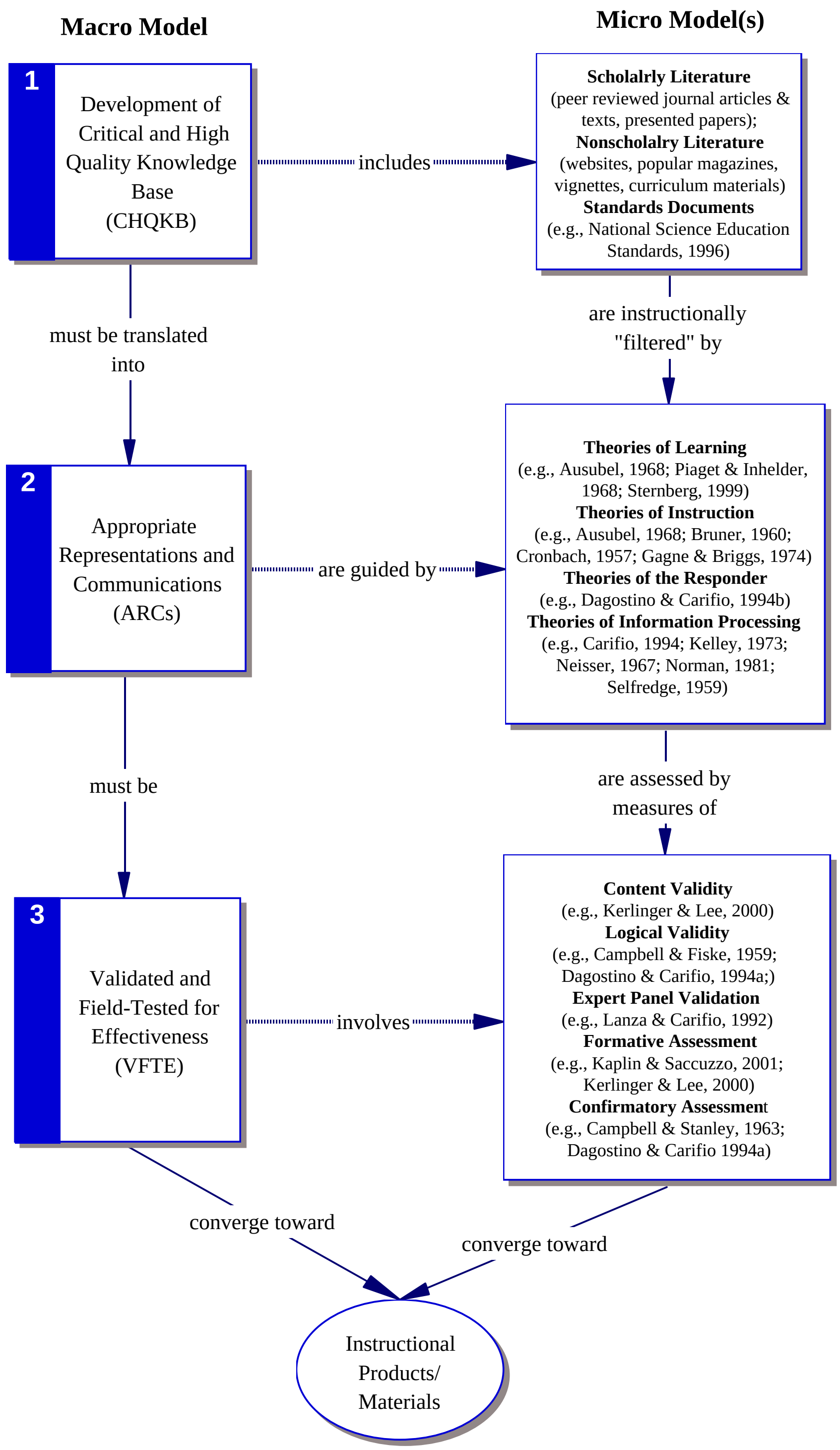


Figure 1. The Specific Formalizations of Carifio's Macro and Micro Models

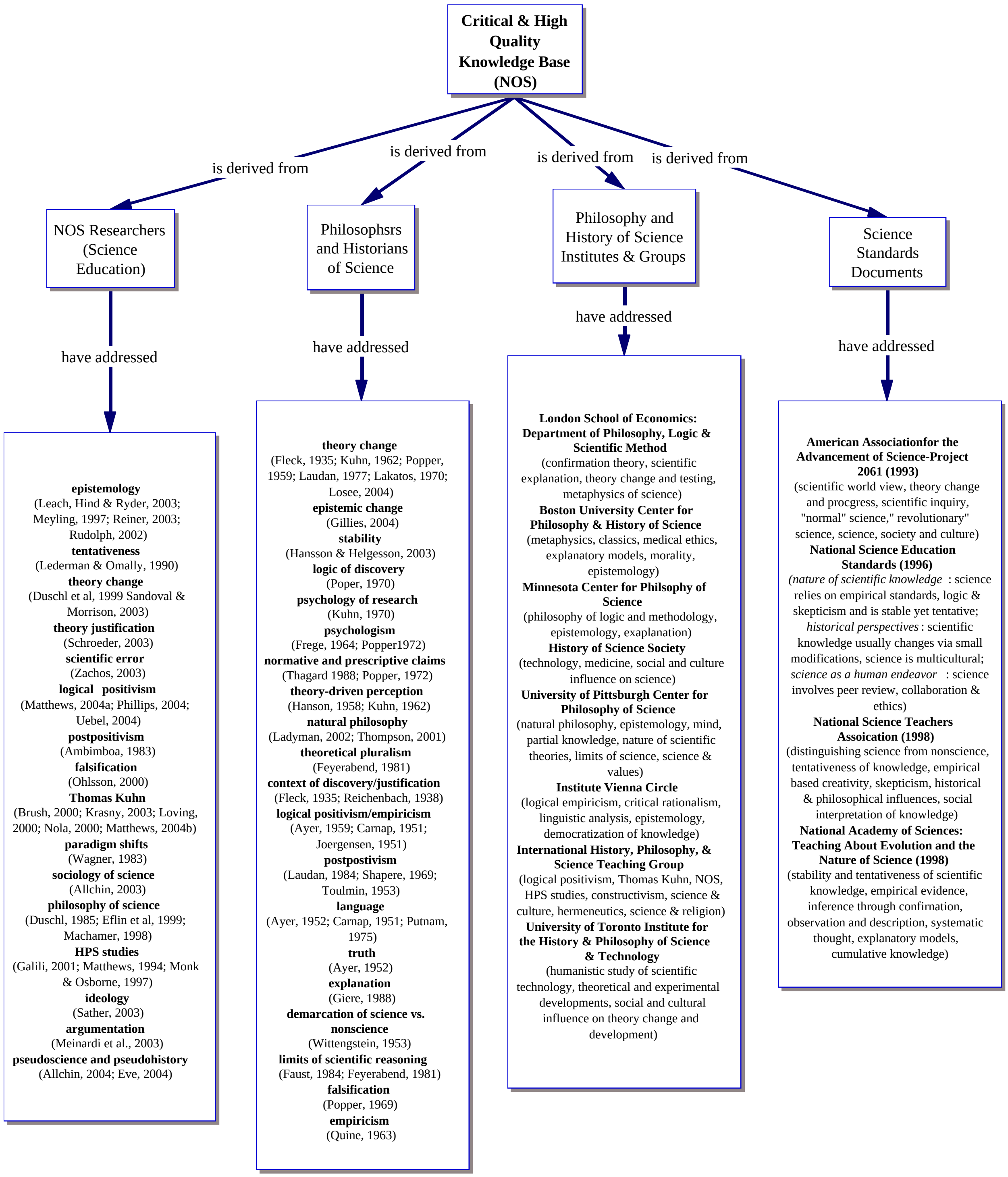


Figure 2. Critical and High Quality Knowledge Base for Nature of Science

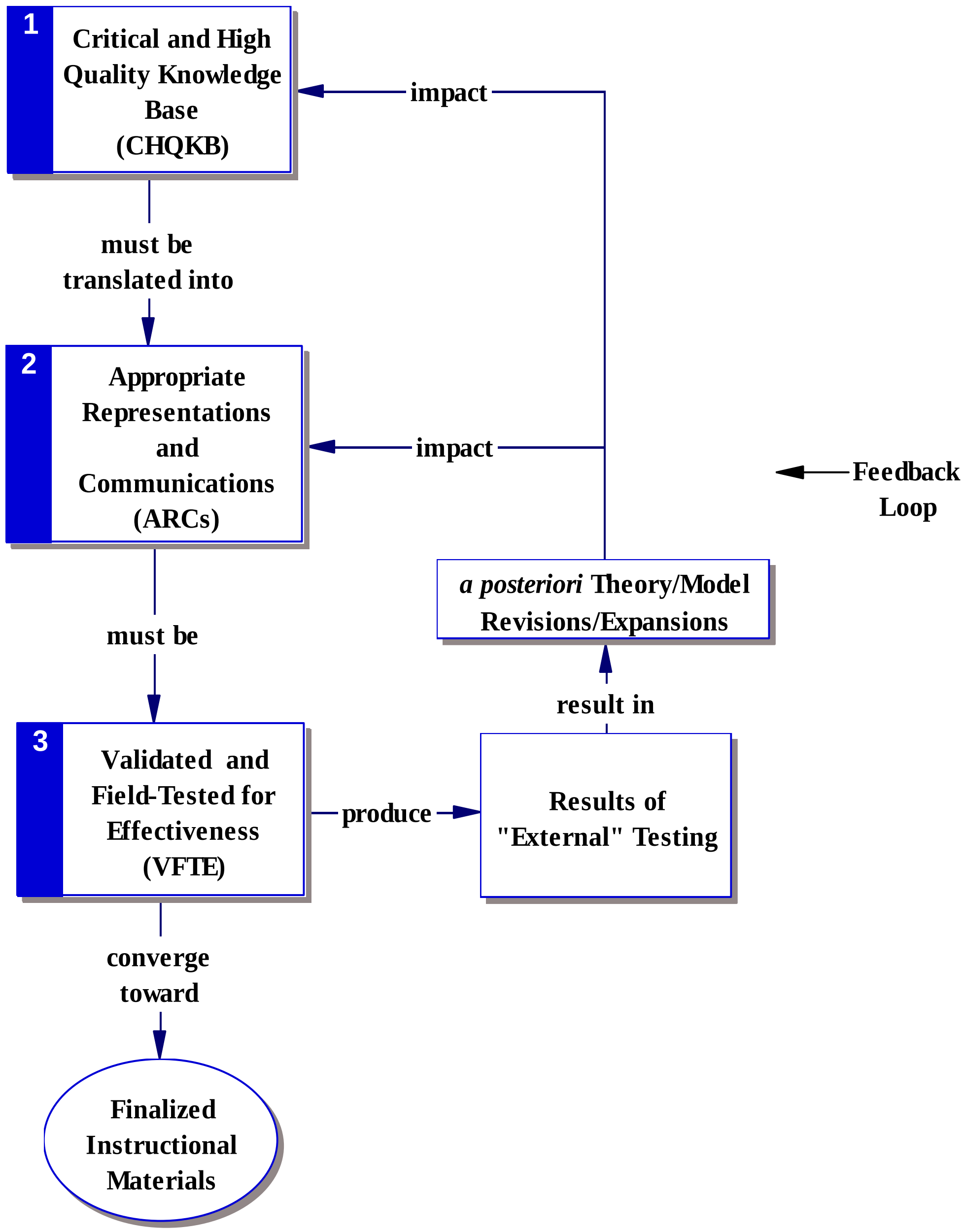


Figure 3. Conceptual and Structural Backbone for Carifio's Formalized Model of Instructional Materials Development

The three macro components of the original model are briefly defined below.

## Critical & High Quality Knowledge Base (CHQKB)

This is a base of knowledge derived from the universe of content it represents that is selected based on a critical selection criterion. This base of knowledge is the result of intense reviews of the scholarly (e.g., peer reviewed journal articles, texts, monographs, books, proceedings and conference papers) and non-scholarly (e.g., websites, popular sources, curriculum materials and professional development materials) literature recovered from a number of different domains such as standards documents, professional associations, primary sources and secondary sources. Critical and High Quality Knowledge Bases are part of a macro instructional model and represent the content that will be translated into instructional materials. The first step in any macro instructional model is defining and developing this type of knowledge base.

### *Appropriate Representations and Communications (ARCs)*

ARCs include but are not limited to instructional materials such as written instructional texts, instructor's manuals, laboratory exercises, charts and diagrams. The word *appropriate* refers to *theoretical appropriateness* or justification, as the initial selection of the representations and communications is required to be justified (logically and empirically) by the theories that will inform the selection process. These theories include but are not limited to theories of learning, instruction, and information processing as well as philosophical considerations related to the nature of the material (i.e., what is the representation at the most fundamental level and how is that justified). The word *appropriate* is an anticipatory, predictive and probabilistic word as one assumes a direct relation between theoretical appropriateness and actual appropriateness as determined by validation and field-testing procedures (see below). Some of the more important (and often ignored) considerations of ARCs include whether the researcher and/or instructional materials developer has: (1) a basic understanding of the learner (e.g., development, aptitude and ability level); (2) a theory of the responder; and (3) a theory of information processing.

*In addition to the three concerns above, the specific nature of the learning and processing task needs to be understood to include considerations relative to (1) text processing and reading comprehension model(s) adopted for the specific ARC; (2) semantic structure and presentation structure of the ARCs; (3) instructional sequencing and content structure of the ARCs; and (4) key ideas and concepts to be taught and emphasized.*

### *Validated and Field Testing for Effectiveness (VFTE)*

The process of validating and field-testing for effectiveness involves statistical and psychometric procedures and principles used to generate information and data that address the *actual* (experimental) appropriateness and validity of a selected instructional representation and communication for a stipulated group. These include procedures and principles such as those associated with measures of content and construct validity, logical validity, ecological validity, internal and external validity and instrument or treatment reliability. These procedures include both qualitative and quantitative methods and the admixture of the two. It is the absence of a systematic, rigorous and theory-based VFTE process and program that is causing such concern in the current educational climate (National Research Council [NRC], 2002), and we believe much of the problem is the lack of macro models of instructional design that incorporate this critical and scientific element of assessment and revision. We are not suggesting that our VFTE method is ideal for all situations (since all instructional milieus are certainly different), but only that curriculum developers and researchers explicitly conceptualize and incorporate a macro structure that includes the VFTE element.

Discussing the theoretical referents in detail for each macro element goes beyond the scope of the present article which is to provide a general description of the instructional materials development model. The theoretical referents associated with each element are described extensively in Perla (2006). It should be clearly stated, however, that there are multiple referents, priorities, and perspectives that could be used in this model. The point of this model is to make these referents explicit and to codify them into a system of instructional materials development that can be used to refine and modify the materials. These points are what we mean by a *formal* model, and what we envision Merton would view as a highly organized approach to purposive social action in a research context. Further, without a clear model of how instructional materials are being developed it is not possible to reliably assess and improve the process since no one knows what the process is.

Having a formal and explicit instructional materials development model, such as the one presented here and shown in Figures 1-3 provided the opportunity to elaborate on this original model by incorporating dimensions that address findings that were *unanticipated* prior to the execution of the research. Incorporating the unanticipated elements into the model led to an elaborated and more comprehensive research model referred to here as the “revised” model. In contrast to the original model, which is a context of justification model, the revised model, introduced below, is both a context of discovery *and* a context of justification model. It is the analysis of the revised model that brings us now full circle back to the main focus of this article: the description of a formal model that accounts for the anticipated and unanticipated consequences of research.

## *Elaborating the Original Instructional Materials Development Model*

As stated above, the macro models and theories in the original model were used to develop a comprehensive knowledge base in a particular domain (nature of science studies) and to translate key and critical features of this knowledge base into appropriate instructional materials validly and with fidelity that teachers and students can understand, operationalize and use. However, in the process of creating these materials, a number of important and unanticipated findings and opportunities were identified that had a major impact on the development of the instructional materials that constituted the major focus of this research. These unanticipated findings seemed to directly impact three diverse yet related fields of study. Briefly, these three related fields of study were (1) education and instruction (and particularly instructional materials development related to NOS studies and the nature of graphics and graphic representation), (2) philosophy (particularly set theory, probability theory and syllogistic reasoning), and (3) cognitive psychology (particularly information processing, text creation, schema theory, and the process of translating and elaborating visual graphic images into corresponding semantic representation). Some of these findings have already been published in international peer-reviewed journals relating to the nature of science (Perla and Carifio, 2008) and research on using visual representations in learning mathematics and scientific content (Carifio and Perla, 2009).

Due to the potential significance and importance of these findings and their complexity, it was decided to carefully characterize and explore these findings as they related to the academic and experimental literature in the above mentioned fields, most of which have experienced explosive growth in a relatively short period of time (i.e., the past 25 years). Similar to Merton, the importance of carefully addressing unpredicted research findings is described by Kerlinger & Lee (2000) in the following terms:

> The unpredicted relation [or finding] may be an important key to a deeper understanding of the theory. It may throw light on aspects of the problem not anticipated when the problem [or research] was formulated. Therefore, researchers—while emphasizing hypothesized relations—should always be alert to unanticipated relations in their data (p. 216).

Consonant with this view of the importance of being open to the potential importance of the unpredicted finding described by Kerlinger & Lee above (see Principle #7), a decision was made to formalize these interesting and unexpected findings relative to the instructional materials developed using the original model and not to ignore, reduce, or trivialize these findings before proceeding to the more formal validation procedures outlined in the research proposal and original design.

The materials and resources used to identify and analyze the unanticipated findings during the instructional materials development process included (a) multiple drafts of each major segment of instructional material edited by the lead researchers (n=4), (b) approximately 150 email correspondences between the two lead researchers, (c) a year long journal (2 volumes) kept by the researchers during the instructional material development process, (d) approximately 35 meeting session notes between the lead researchers and development team, (e) a file kept by the lead researcher labeled "interesting findings and speculations" with over 400 individual thoughts and reflections and (f) a list of researchers, theories and experiments that the lead researcher become aware of that address, to varying degrees, the interesting (many unanticipated) findings and speculations encountered and documented during the instructional materials development process.

A content analysis and modified Q-sort technique was used to create general categories for the unanticipated findings.

Each individual note or observation (data unit) collected and documented during the materials development process was assigned to a separate and unique general category. Once these individual data units were assigned to a general category, the data units in the categories were again content analyzed and further broken down into sub-categories and cross validated by two experts in cognition and instructional materials development. Table 1 shows the general categories and sub-categories for the unanticipated findings identified during the content analysis. The general and sub-categories for the unanticipated findings in Table 1 provide the data used to identify and organize the unanticipated research findings. It should be pointed out that although each general category in Table 1 (Cognition, Instruction and Philosophy) is associated with one or more of the main findings identified here, not all general or sub-categories documented during the research were directly associated with or contributed to a main finding.

Table 1
Overview of the General Categories and Sub-Categories that Emerged from the Content Analysis during the NOS Instructional Materials Development Process

| General Categories | Cognition | Instruction | Philosophy |
|---|---|---|---|
| Sub-Categories | schema theory<br>knowledge representation<br>graphic representation<br>text elaboration<br>metacognition (as a construct)<br>epistemological standards | interdisciplinary<br>learning<br>curriculum<br>instructional development<br>metacognition (as learning aide)<br>purposeful text generation | probability (classical)<br>probability (non-classical/<br>fuzzy)<br>logic<br>pseudoscience<br>theory criteria (demarcation)<br>theory change<br>positivism<br>postpositivism |

It should also be noted that the ability to recognize, explore and organize these unanticipated findings, even using a formal model, would have been far more difficult without the careful and consistent documentation of the difficulties, struggles, questions, problems and “Ah-ha” moments encountered during the 12-month long materials development process, which was part of the original methodology of the research. It was not until the hundreds of analytical memorandums, notes, journal entries and reflections were content analyzed, sorted, and studied that (1) it was realized that the original instructional materials development model used in this research did more than serve as a logical and formal framework for instructional materials development, but that this model also contributed to the development of new (unanticipated) theoretical insights related to (a) the learning sciences and (b) the content being taught, and (2) that these systematically organized unanticipated findings could be used to further develop and elaborate the original instructional materials development model used in this research. These last two points in many ways substantiate Merton's (1936) position that *organized* purposive social action makes it easier to analyze and conceptualize unanticipated outcomes (see Principle #4 above). However, the structure provided by the original model alone (see Figures 1 & 3), was necessary but not sufficient to recognize important unanticipated findings during the research. Indeed, it was the careful and assiduous documentation of difficulties and insights (i.e., reflections and meta-cognitions) encountered during the research in the context of the formal model that gave rise to research observations of the unanticipated type. In this case and in this context, it could be argued that innovation (links to unanticipated findings) followed design (use of a formal model).

At this point in the analysis, the following eight *theoretically-based* assumptions were made about the original (formal) instructional materials development (IMD) model in Figure 1 based on the experiences and findings associated with this research:

1. The original IMD model includes macro elements and micro elements that can be developed and *explicitly* used to provide a conceptual and structural framework for important issues related to the IMD process;
2. Interactions exist between the different macro (and micro) model elements in the original IMD model (i.e., CHQKB, ARCs and VFTE);
3. The original IMD model is capable of identifying and modeling the interactions between different macro elements in the IMD process;
4. The consequences of the interactions between macro elements may be expected or unexpected;
5. One of the most difficult aspect of executing the original IMD model is operationalizing the content and knowledge base (i.e., CHQKB) in the most instructionally sound and appropriate (theory-based) manner (i.e., ARCs);
6. It is likely that the unexpected findings exist *between* the macro model elements, as this is where the operationalization of the macro elements and execution of the research occurs;
7. A highly organized formal model of IMD can be used to logically and systematically map unanticipated research findings, thereby creating a more comprehensive research model and form; and,
8. The original model of IMD is necessary but not sufficient to maximize identification of unanticipated findings and relied on the careful and consistent documentation of difficulties and insights encountered during the research.

With these principles established, the original IMD model in Figure 3 can now be extended and elaborated in a way that addresses the emergence and significance of the unexpected findings of this research.

## Defining the Revised Instructional Materials Development Model

As can be seen in Figure 4, the revised version of the original model used in this research includes an *expected* and *unexpected* section and trajectory (defined below). The backbone of the original model (sections labeled 1, 2, and 3 in Figure 3) defines the *expected* area and remains intact in the revised version of the model in Figure 4. However, unlike the original model, the revised model includes an *unexpected* column or trajectory, as well as certain spaces in the expected section and their associated concepts and principles. Each of the key concepts and principles of the revised model in Figure 4 is defined and discussed next.

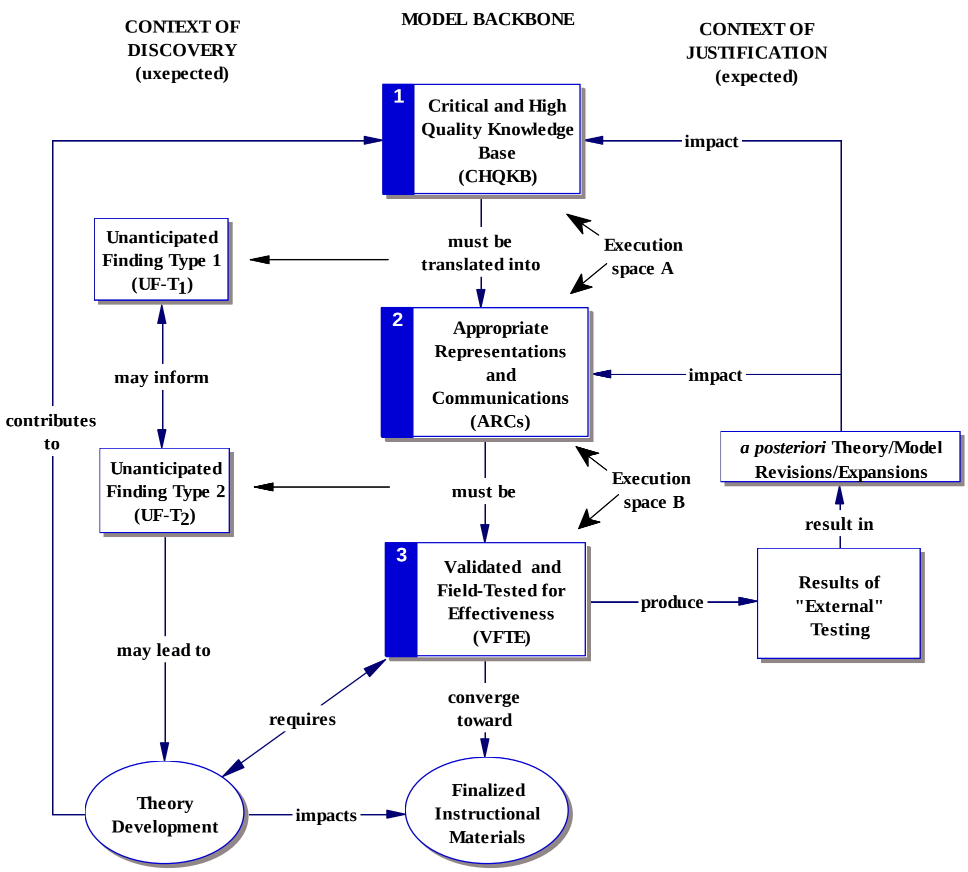


Figure 4. Revised and Elaborated Version for Carifio's Formalized Model of Instructional Materials Development and Theory Development

### *Expected and Unexpected Findings*

The expected column in Figure 4 represents the general expectation that using the Critical and High Quality Knowledge Base (CHQKB) would lead to Appropriate Representations and Communications (ARCs) that could be Validated and Field Tested for Effectiveness (VFTE) ultimately leading to high quality Instructional Materials that are subject to revisions and modifications.

This process defines the context of justification frame of the model. The unexpected column in Figure 4 is where the unexpected findings are modeled in the process of executing the research program. This is the context of discovery frame of the model.

The qualitative differences between expected and unexpected findings may be depicted in different ways. For example, a two column idealized model is a simple and linear way to represent transitions from the CHQKB to ARCs to VFTE with no consideration for any finding that may exist outside the scope of expectation or execution. Findings that are only perceived as directly applicable, useful, or related to the research (within the scope of expectation and execution) are defined as *expected findings*. This linear, simple, practical and idealized view of the expected finding was the view initially adopted for this research in relation to the original model.

However, a more realistic version of research findings allows for and considers findings both *directly and indirectly* related to developing and/or validating instructional materials that exist outside the scope of expectation and execution, or at least exist along the periphery of the scope of expectation and execution. Findings outside the scope of expectation or execution are defined as unexpected or unanticipated. Unexpected findings may be represented in the boxes or additional columns labeled Not "B" and Not "C" in the two-column simple model (Figure 5). Also, note that the links from points A to B to C in the "realistic" version of the model are wavy and not straight like the points in the idealized (linear) version. The wavy lines emphasize the point that even (logically) expected outcomes are not completely direct or linear, but are often acquired in a dynamic, circuitous and nonlinear fashion.

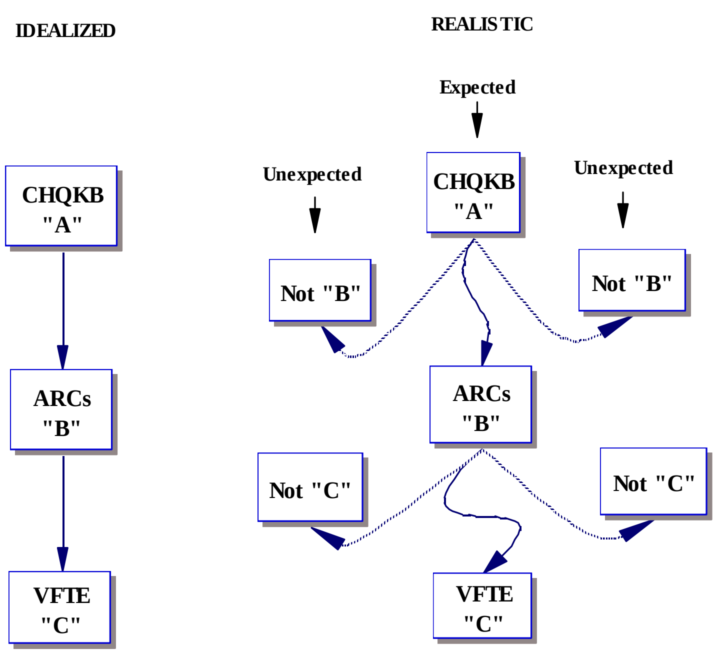


Figure 5. Hypothetical Locations and Relationships of Expected and Unexpected Findings

This model of expected (core) and unexpected (peripheral) findings during the research process is similar to the Lakatos (1970) model of research programs in science where a theoretical hard core is surrounded and insulated by auxiliary hypotheses that form a protective belt around the hard core. To draw an analogy between the model in Figure 4 and the Lakatosian model, the expected findings would represent the theoretical hard core, while the unexpected findings are similar to the auxiliary hypotheses of the protective belt. A formal model and mapping of both expected and unexpected research findings or experiences is consistent with a more probabilistic and uncertain (Getoor, Friedman, Koller & Taskar, 2002), emotive (Barnes & Thaggard, 1996), interactionist (Cronbach, 1957, 1975) and fuzzy view of information processing and human cognition (Zadeh, 1965) and decision making (Tversky & Kahneman, 1981). Further, a formal model and mapping of both expected and unexpected research findings is consistent with the now mainstream view of the nature of science that recognizes that both the context of discovery (and unexpected findings) and the context of justification (and expected findings) are two sides of the same research coin that cannot logically be separated without serious implications (see Carifio, 1976 and Perla and Carifio, 2005 and 2009 for details). If the unexpected finding contradicts a core principle of the guiding theory (what Kuhn called an anomaly), it could lead to what Kuhn (1996) called extraordinary science—a period where the assumptions of the existing knowledge base are called into question. If enough of these anomalies accumulate and cannot be explained with the current theory, and an alternative theory is suggested, a rare paradigm shift may occur. To the extent that a model of unanticipated findings demonstrates the process by which current theories lead to their own rejection or major revision, Kuhn's view that old and new world views are incommensurable is significantly weakened or becomes an illogical comparison in the first place.

## *Execution Space*

The *execution space* in Figure 4 is the space between the macro-model elements (i.e., CHQKB, ARCs and VFTE) that represents the researcher's execution and operationalization of one macro model (e.g., CHQKB) in order to get to the next macro model (e.g., ARC). The execution space is the act of doing the research, and it is where the researcher encounters the practical limitations, difficulties, frustrations and insights of going from *theory to practice* or from *theory to product*. The execution space is where the interactions and relationships between macro model elements manifest in real time. As can be seen in Figure 4, there are two execution spaces (A and B) in the revised model. Execution space A is where the researcher begins the process of translating the CHQKB into ARCs and terminates after the ARCs have been developed in some accepted form. Execution space B (not yet entered in this research) is where the researcher begins the process of validating and field-testing the ARCs to see if and how they actually work in different situations. This research had only engaged execution space A in the process of developing instructional materials to teach about the nature of science, while execution space B is currently in progress. The process of engaging execution space A during this research was extremely difficult, frustrating and led to a number of unexpected and unanticipated results and findings, which were briefly discussed earlier. The concept of an execution space makes it possible to formalize and model Merton's (1936) view that the consequences of purposive social action are the outcome of specific actions "which would not have occurred had the action not taken place" (p. 895), as the execution space in Figure 4 is clearly the key generative aspect of the elaborated model. Further, in the context of the revised model in Figure 4, there appear to be at least two qualitatively different types of unanticipated findings (Type 1 and Type 2). Both of these different types of findings are discussed next.

## *Unanticipated Findings: Type 1 (UF-$T_1$) and Type 2 (UF-$T_2$)*

Unanticipated Type 1 *(UF-$T_1$)* are findings encountered in *execution space A* that are associated with the difficulties, frustrations, problems and insights encountered in generating ARCs from the CHQKB that are not *directly* related to the aim of the research (i.e., creating and developing ARCs). Of course, it is difficult to account for every possible unexpected finding, as some unexpected findings may be more significant than others and some unexpected findings may be distractions or cognitive intrusions. The significant unexpected findings encountered during this research were all Type 1 findings, as the research only engaged execution space A (see Figure 4).

Unanticipated Type 2 *(UF-$T_2$)* are findings encountered in *execution space B* that are associated with the difficulties, frustrations, problems and insights encountered in the process of validating and field-testing ARCs that are not *directly* related to the aim of the research (i.e., validating specific ARCs). Examples of struggles, problems, difficulties or insights a researcher might encounter in execution space B would be issues that emerge once the validation studies and field-testing is under way (such as fidelity of implementation and the presence of intervening or interacting variables) that lead to insights about new research and statistical methods and techniques. In fact, many new research methods and new statistical and psychometric techniques have developed not as a result of the initial research questions being asked, but rather as a result of anomalous and strange findings encountered during the research that were only indirectly associated with the initial research questions (Kerlinger & Lee, 2000). For example, Glass' discovery of meta-analysis and Ebbinghaus' discovery of the rudiments of the t-test could be characterized as Type 2 findings. As mentioned above, execution space B was not engaged in the original study reported here, but has been engaged subsequently and is associated with numerous unanticipated (methods-based) insights relative to the process of field-testing and validating the ARCs (Carifio and Perla, 2009). Further, numerous prior studies using Carifio's (1977) original model have uncovered unanticipated findings that in hindsight can be effectively characterized as UF-$T_2$) (see Perla, 2006 for details).

Table 2 summarizes the key features of Type 1 and Type 2 unexpected findings. As shown in Table 2, Type 1 findings are those findings that occur when going from the Critical and High Quality Knowledge Base to the Appropriate Representations and Communications (execution space A) and are more *qualitative* in origin. Type 2 findings are those findings that occur when going from Appropriate Representations and Communications to Validating and Field-Testing the ARCs (execution space B) and are more *quantitative* in origin.

Table 2
Summary of the Two General Categories of Unexpected Findings Postulated

| | General Category | Route | Execution Space | Research Category |
|---|---|---|---|---|
| Type 1 | Unexpected | CHQKB→ARC | A | More qualitative |
| Type 2 | Unexpected | ARC→VFTE | B | More quantitative |

Perhaps the most important insight about the revised model in Figure 4 and its associated table (Table 2) is the idea and possibility that (1) qualitatively different types of unexpected findings exist and that a *taxonomy* of such findings might be possible to develop and (2) these qualitatively different types of unexpected findings can come together, inform one another, and lead to new methods, theories or significant advances and extensions of existing theories. As pointed out in relation to the main unexpected findings in this research (all Type 1 findings), these findings are likely to have a significant impact on a number of different yet related fields such as cognition and instruction and provide a fund of fresh ideas to be explored and tested.

## Discussion

A number of important points can be made regarding the revised model of the consequences of research findings and how it challenges current thinking along a number of different educational dimensions. These points are discussed below.

### *Nature of Instructional Materials Development*

The insight that a formal model of instructional materials development can be used to create and extend existing theories and methods in primary disciplines (such as cognitive psychology and learning sciences) has the potential to transform the image and function of the instructional materials developer (and development process) from a theory (knowledge) consumer to a theory (knowledge) producer. In the rush to generate and produce quality instructional materials, instructional materials developers, educational researchers and knowledge managers in general may not recognize the potential impact of their work as it relates to the unexpected and unanticipated findings, and the possibility that such findings may significantly contribute to methodological and theoretical developments in primary disciplines. In fact, the main (unanticipated) findings of this research were almost ignored in order to move the research along as intended. One can only imagine the lost opportunities for theoretical advancement in the countless studies, dissertations, books and research initiatives that may have been ignored, reduced, or trivialized an important unanticipated finding for the sake of rigidly following the research course. A model and taxonomy of the unexpected finding, like the one developed in this article, could be used as a tool to help researchers maximize their efforts and provide a more complete picture of research and knowledge development.

## *One Way Trap Functions*

Although Merton argued that we can better study and understand the nature of unanticipated consequences of purposive social behavior more readily with organized behavior, compared to behavior and activities that are less organized in structure, he was not sanguine about the possibility of creating general and more predictive models of such behavior due to the complexity of human behavior and thought. Indeed, Merton argued quite clearly that due to the complexities of human behavior and the range of possible outcomes associated with any pair of psychological variables, it is impossible to develop a formal system of highly reliable predictions, such as those, say, in the physical sciences. Under this assumption, Merton points out that it is impossible to predict with certainty the results of any particular case as our conceptual categories, problems and theories are usually not homogeneous enough for such prediction to occur (pp. 898-899), and we need to be prepared for the unexpected and unanticipated and not surprised or flummoxed by them. Few if any cognitivists would argue against Merton's position that the complexities of human behavior make precise predications of such behavior impossible—or at a minimum extremely difficult. But they would also argue that one may be prepared for the unexpected and fortuitous finding.

Nonetheless, Merton strangely positioned himself on the most difficult (and intractable) end of a *one-way trap function*, leading to the logical conclusion that models of unanticipated consequences of purposive social actions, even in general form, are an impossibility. For example, in a one-way trap function, it is virtually impossible to determine the specific mathematical operation used by another person to reach a specific number, say, 245, because the possible combinations of different mathematical expressions producing such a number (viable range of consequences) are infinite. However, with the knowledge that we are multiplying two numbers (e.g., 35 and 7), we are certain of the product (245) and how it was reached (i.e., the function only works *one way* with complete certitude in some axiomatic contexts). In general, the more parameters and limits we impose on the problem (e.g., that we are only allowed to multiply two numbers one time, or that we are only allowed to multiply a 2-digit number by a 1-digit number one time), the more we reduce the *uncertainty* of the specific function and factors used to achieve a result.

The one way trap function analogy serves here to demonstrate that we can only increase our degree of predictive value when the elementary components of a model or system are known and well established, and that such prediction is extremely difficult and unreliable when we deal only with an outcome, even if the outcome is contextualized. As Merton correctly points out, and as modern findings in cognition research tell us, it is quite impossible to know or anticipate each human factor determining behavior and to consistently and reliably map these factors to a specific cause.

But this problem can be addressed by focusing on the general (macro) aspects, products and categories of purposive social action *initially* (which is a form of meta-cognition), versus the individual (micro) details that have little predictive value when applied to the subtleties of human behavior and decision-making (i.e., starting backward in a trap function). By addressing the general products and tendencies of purposive social action, specifically research, we can create general boundaries that limit where and how the micro elements emerge and their range of consequences. It should be noted that this structured and emergent design, versus the bottom-up approach of Merton, is a fundamental principle of chaos theory and complexity science which has paid large dividends in the fields of engineering and manufacturing (Morley, 2003). Indeed, the only way to effectively address the one-way trap function in complex research situations is to re-create systems anew in the general sense and to see (and carefully document) how the model populates itself (i.e., playing God). To do this requires that the general model be well defined (yet highly flexible) and context specific, as different general models will have different sets of parameters, factors and theoretical referents. This article demonstrates how a well described (theory-based) general model of instructional materials development populated itself and led to a crude taxonomy of unanticipated findings in a research setting. More work and consideration with these types of taxonomies and models are needed.

## *Unanticipated Findings Acquisition Device*

The definition and views of language, information processing and research are similar and often overlooked. Ashcraft (2002) defines language as a purposeful activity and “a shared symbolic system for communication” (p. 350); and it is hard to think of a more appropriate definition of research or the intent of the research process. Similar to the seminal work on language acquisition and development outlined by Chomsky (1957) that argues that language has a formal structure and hierarchical organization that governs its development and expression, the human process of *executing* research may have a built in system or device for the acquisition of unanticipated findings that, like language, becomes apparent when considered in the context of organized structures. Indeed, the research described here, as well as basic research in the cognitive sciences, suggests that the incompleteness of knowledge and understanding that defines human action and thought inevitably gives rise to findings that were found but not sought, and that these findings are more readily brought into consciousness through a formal structure (like that in Figure 4) *and* serious reflection. The view of research suggested here, therefore, is quite different from traditional views and the challenge to model, map and parameterize (even in rough form) unanticipated research findings is critically important because it provides the only hope for ever gaining any level of predictive mastery over a phenomena that has, for the most part, been relegated to the domain of the metaphysical.

## *Educational Practice and/or Research*

Recently, in an article in the *Educational Researcher* titled *Reclaiming Education's Doctorates: A Critique and a Proposal*, Shulman, Golde, Bueschel & Garabedian (2006) make a compelling argument that we desperately need to draw better and more distinct lines between practitioners and researchers in education in order to improve the practice of education (somewhat analogous to the MD and PhD degrees in medicine with their different yet fundamentally related aims of helping patients). As Shulman et al argued "The problems of the education doctorate are chronic and crippling. The purposes of preparing scholars and practitioners are confused; as a result, neither is done well" (p. 25). Although the views of Shulman et al are difficult to argue against and shared by many educational scholars (e.g., Fensham, 2004), this view implies that practitioner-based research cannot lead to substantive insights related to educational research. The research and model outlined in this article clearly suggests otherwise, and that a practitioner-based research activity (e.g., development of instructional materials) can lead to important research-based insights when done thoughtfully and meticulously and when guided by a theory and formal model. The view of Shulman et al assumes quite correctly that many practitioners (and researchers) are ill equipped to do good, rigorous and theory-based research, but incorrectly assumes that practitioners do not have the opportunity to make substantial research gains, or to be trained to identify important (and often unanticipated) findings in their practice-based research activities that have major implications on the nature of educational research and its defining methodological and theoretical edifices. Indeed, one of the underlying arguments developed in this article and work, substantiated by numerous historians and sociologists of science, is that practitioner-based findings of the unanticipated type (whether practitioners in medicine or other fields of study) have traditionally had the largest payoff for humanity vis-à-vis the well formulated plans of the trained researcher and their anticipated outcome models. In the model of Shulman et al, practitioners become marginalized by others and even begin to marginalize themselves and their research (see Geelan, 2006 for an example of this).

As mentioned earlier, the insight that a formal model of instructional materials development can also be used to create and extend existing theories and methods in the learning sciences has the potential to transform the image and function of the instructional materials developer (and development process) from a theory (knowledge) consumer to a theory (knowledge) producer. This particular image, role change and redefinition of the material developer and the materials development process is most appropriate for higher education faculty as it is a view, theory and model that is highly consonant with the core features of their professional identity and their professional and scholarly functions, and what the ARC component of the model presented here does is to both formalize and validate these points, functions, and role definitions.

## *A Word of Caution*

This article began with a discussion related to the nature of the unanticipated consequences of purposive social behavior, where purposive behavior was interpreted as educational research, and documented the lack of formal attention and interest this concept has generated over the past seven decades. Although the findings and models developed in this article are to some extent empirical (and not merely speculative), the lack of research in this area makes many of the ideas in this article appear perhaps more anticipatory and "fringe-like" than they actually are. Nevertheless, there are important limitations to any model of unanticipated findings and the qualitative methods used to map, model and process them. The most conspicuous limitation of such an approach to research is the value (or pseudo-value) one may ascribe to unanticipated findings. In noting concerns associated with unpredicted and unexpected findings, which may be overdone (see Kerlinger & Lee, 2000, p 217 for details), one must not miss the major point that a formal and explicit model or theory of some kind is needed as a (meta-cognitive) control mechanism to help ensure that over-cooking does not occur and unanticipated findings are not overdone. As mentioned earlier, the relationship between findings (expected or not) and their theoretical base is the necessary first step needed to logically develop a construct, make reasonable predictions, and subsequently test these predictions. To achieve this logical and controlled flow from constructs to predictions to tests, a full and not partial model needs to be utilized like the full model and taxonomy of anticipated and unanticipated findings outlined here.

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