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A Role for Formalisms in Integrative Studies

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Abstract: The increasing importance of integrative studies in higher education makes it more vital to rethink integrative studies from the perspective of reaching maximum benefit. In rethinking integrative studies, it is appropriate to subsume a number of active concepts under more embracing rubrics. Also it is noteworthy that subsumption does not destroy or eliminate the active concept, does sustain the capacity to use the active concept appropriately, and does provide elbow room both for perceiving that concept within the larger rubric, and for reconceptualization of the active concept within the more embracing rubric.It is certainly appropriate as well to rethink the possibility that, in developing integrative studies in higher education, we can and should draw more heavily upon guidance from selected scholarly predecessors than we appear now to be doing, whether they were academics or not. Then, this guidance can also be integrated with any relevant knowledge under exploration at present. Finally, appropriately, we should consider the possibility of applying classical formalisms from formal logic, using computer assistance (which makes those formalisms readily available, and does not require understanding of their symbolic systems or operations as a precondition of their application) as a way of enhancing the breadth and quality of integrative studies: especially of those that involve complexity.

> For to say truth, whatever is very good sense must have been common sense in all times; and what we call Learning, is but the knowledge of the sense of our predecessors....I fairly confess that I have serv'd my self all I could by reading; that I made use of the judgment of authors dead and living; that I omitted no means in my power to be inform'd of my errors, both by my friends and enemies. But the true reason these pieces are not more correct, is owing to the consideration how short a time they, and I, have to live.—ALEXANDER POPE (1688-1744). (Butt, 1963, pp. xxvii-xxviii.)

It Is at Least Possible

It is at least possible that, in developing integrative studies in higher education, we can draw more heavily upon guidance from our scholarly predecessors. To this end, I offer good assumptions and bad assumptions.

Bad Assumptions

Here are some of the bad assumptions that are broadly relevant to issues pertaining to integrative studies involving complexity (as many inherently do).

1. Linguistic adequacy. That received (natural) language is adequate to present and clarify a unity counter-argument (Foucault, 1993).
2. Adequacy of simple amalgamation of disciplines. That when one academic discipline is inadequate for coping with a situation, it is only necessary to bring in representatives of two (or sometimes three or more) disciplines and this will, without applying any proven integrative process, assure resolution of the situation.
3. Sufficiency of normal processes for resolving problematic situations. That normal processes, e.g., those taught in academia for resolving problems in two hours or less, can readily be exported to deal with situations much greater in scope than those repeatedly dealt with in higher education. This assumption is especially prominent for those normal processes which produce numerical results.
4. Location of complexity. That complexity is located in the system under observation, i.e., the system that is the subject of the inquiry, or the topic of the lecture.

Key terminology in these assumptions will be clarified later in this paper.

More Bad Assumptions

Here are additional bad assumptions that apply more narrowly, specifically to integrative technology issues, for example:

5. Validity of received doctrine. That received doctrine is correct or nearly so.
6. Breadth of relevance of quantitative formalisms. That quantitative formalisms are almost always sufficient to provide a basis for effective action.

7. Breadth of application of quantitative formalisms. That most quantitative formalisms have broad application.
8. Empirical evidence unneeded from prestigious sources. That if received doctrine comes from prestigious sources without supporting empirical evidence it should not be challenged.

Enhancing the Quality of Knowledge

If knowledge is perceived as depersonalized belief, as seems consistent with the views of Michael Polanyi (1958) (although the concept of *personal knowledge* then becomes an oxymoron, better replaced with a *personal belief* concept, along the lines studied by C. S. Peirce), one may wish to know the origins of the beliefs that came to be part of accepted knowledge. Foucault has amply discussed matters pertaining to the inadvisability of routine acceptance of knowledge, done without regard to the origins of the beliefs and the circumstances that justified acceptance. (Foucault, 1993) Earlier, F. A. Hayek sounded a very similar theme:

> The discussions of every age are filled with the issues on which its leading schools of thought differ. But the general intellectual atmosphere of the time is always determined by the views on which the opposing schools agree. They become the unspoken presuppositions of all thought, the common and unquestioningly accepted foundations on which all discussion proceeds. When we no longer share these implicit assumptions of ages long past, it is comparatively easy to recognize them. But it is different with regard to the ideas underlying the thought of more recent times. (Hayek, 1955, p. 367)
>
> As Bernard Bosanquet once pointed out, 'extremes of thought may meet in error as well as in truth.' Such errors sometimes become dogmas merely because they were accepted by the different groups who quarreled on all the live issues, and may even continue to provide the tacit foundations of thought when most of the theories are forgotten which divided the thinkers to whom we owe that legacy. When this is the case, the history of ideas becomes a subject of eminently practical importance. It can help us to become aware of much that governs our own thought without our explicitly knowing it.(Hayek, 1955, pp. 367-368)

It now appears to be more necessary than ever before to look to those specific scholars whose beliefs are relevant to assessing what is acceptable today as knowledge. This matter is particularly relevant to integra tive studies, and to interdisciplinary practices, because the possibility exists that multiple branches of knowledge have or will become the object of integration when, alas, those individual branches are themselves questionable, and frequently are not internally integrated. The consequences include the possibility that interdisciplinary integration will be frustrated by defects in disciplinary knowledge, and that Foucault's complaints will be compounded indefinitely into the future.

Basic Propositions for Change in Academia

Good Assumptions

Now it is time to look at those good assumptions that will be examined in more detail following their enunciation. The following set of good assumptions is presented in a designed sequence, because these assumptions are interlinked. The context in which these assumptions are offered is academia, i.e., colleges and universities as a whole. Key aspects of these assumptions will be discussed later in the paper.

1. Foucault's conclusions. The conclusions reached by Michel Foucault (1926-1984) concerning the necessary reconstruction of knowledge are correct, for the reasons that he has given (Foucault,1993).
2. Lasswell's infrastructure conclusions. The infrastructure conclusions reached by Harold Lasswell (1902-1978) concerning necessary conditions for developing effective public policy and for facilitating learning about broad-scope situations are correct, for the reasons that he has given (Lasswell, 1960, 1963, 1971).
3. Peirce's insights. The insights produced by Charles Sanders Peirce (1839-1914) about the role of logic, ethics, and esthetics in science and, more generally, in making our ideas clear, are correct, for the reasons he has given (Peirce, 1878/1991, pp.160-179).
4. Harary's mathematics. The mathematics of Structural Models, as set forth by Harary (1921-), which aggregates various mathematical unities into a larger unity, provides the mathematical basis for portraying the logic of disciplines through structural models (Harary, Norman & Cartright, 1960).
5. Warfield's interpretive structural modeling process. The process developed by Warfield (1925-) called *Interpretive Structural Modeling*

(ISM) provides the computerized technological support (and insulation from not-understood mathematics) required to carry out the program of Foucault, applying the conceptualization set forth by Peirce, and converting Harary's analysis into a synthesis format (Warfield, 1974, 1976).

6. The Generic Design Science and Interactive Management. *The Science of Generic Design* and the management system called *Interactive Management (IM)* developed by Warfield and his colleagues (Warfield, 1994, Warfield & Cárdenas, 1994) provide, respectively, the scientific foundation for collaborative system design, and the management practice to implement that scientific foundation. Incorporating ISM, IM provides the management processes required to carry out the program of Foucault, applying the conceptualization set forth by Peirce.

7. The Infrastructure for Knowledge Development. The special infrastructure required to carry out the IM processes consisting of (a) the Demosophia room and (b) the Corporate Observatorium, both based in Lasswell's contributions, constitute the means to support the program of Foucault, applying the conceptualization set forth by Peirce, using the relevant Lasswell infrastructure conclusions (discussed later).

8. The Spreadthink Discovery. The discovery and articulation of *Spreadthink* (Warfield, 1995) revealing the universal variations in viewpoints associated with situations involving complexity, provides the rationale for dispensing with all non-scientifically-based group processes and dispensing with conventional group work environments, in favor of a process and infrastructure that is adequate to meet the demands of complexity.

9. Indexes of Complexity. The failure of academics and business managers to recognize the special requirements for success in working with complexity can be rectified, if the actors will gain an understanding of recently developed indexes of complexity (Staley, 1995). The application of these indices will make clear when situations have to be dealt with in full recognition of the demands of complexity.

10. The Boulding explanation for low intellectual productivity (Boulding, 1966). Kenneth Boulding's explanation for low intellectual productivity can be applied to say why the ideas reflected in the foregoing nine points are slow to make inroads into academic institutions and other organizations. Put in a vernacular, (1) people frequently copy indiscriminately (with minor editing) what other people do without analyzing why that is a bad idea, (2) people are basically ill-equipped to prioritize ideas according to their importance, and so they work on less-important ideas,

instead of assigning the proper importance to coming to grips with complexity, and (3) cultural change is inherently slow, because those with power attained that power by pursuing conventional approaches to difficult situations; and they don't see any reason to throw off those processes in favor of something they have not experienced (and can't or won't take the time to study or experience).

The Problematic Situation and the Language of Inquiry

A key issue in developing an integrative studies concept and practice involves the context within which integrative studies are carried out. The very term *interdisciplinary* immediately tends to narrow the context to include only those topics or themes that can be developed by an integration of academic disciplines. There is a powerful argument for adopting that context. The argument basically is that it is inside the institutional entity (i.e., the college or university), in which scholarly advancement of knowledge is most likely to occur. The institution, through integrative practice, is best-positioned because of the breadth of its component understandings to focus upon integrative studies while, at the same time, producing educational benefits for students and faculty alike.

On the other hand, it is very clear that if integrative studies are limited to content found in academic disciplines, a large sector of opportunity for application is not overtly factored into the activities. Even more disappointing is an issue related to creating a language of integration to carry over directly to non-academic pursuits. The cost of replacing the word interdisciplinary with a more encompassing term, e.g. *adisciplinary*, seems modest, and the benefits seem potentially large. In so doing, the word interdisciplinary need not be dispensed with. On the contrary, it may become more linguistically acceptable (i.e., more authentic in usage) because it can be used as a restricted, but very focused, case of a more encompassing concept. It is notable that Foucault, in considering the requirements for broad knowledge reconstruction, chose the word *unity* to represent the higher genus of which *discipline* is a lower-level constituent.

The Initiation of Inquiry

It is perfectly possible that any inquiry, be it disciplinary, interdisciplinary, adisciplinary, or otherwise, can be doomed to failure simply because it begins with an underpinning of a bad assumption about the initiation of inquiry. Several philosophers have explored the issue of how to start an inquiry. Some of these have been discussed in an integrated context by the late F. S. C. Northrup (1947/1979). In comparing various incompatible views, one may conclude that the most appropriate view can be found by joining ideas from C. S. Peirce, John Dewey (at one time, briefly, a student of Peirce), and the Chinese tao of science.

Peirce dismissed Descartes' idea that the way to begin is to clear the mind, writing that one must recognize that the individual is endowed with a mass of cognition which could not be dispensed with, even if one wanted to:

> Philosophers of very diverse stripes propose that philosophy shall take its start from one or another state of mind in which no man, least of all a beginner in philosophy, actually is. One proposes that you shall begin by doubting everything, and says that there is only one thing that you cannot doubt, as if doubting were "as easy as lying." Another proposes that we should begin by observing "the first impressions of sense," forgetting that our very percepts are the results of cognitive elaboration. But in truth, there is but one state of mind from which you can "set out," namely, the very state of mind in which you actually find yourself at the time you do "set out" — a state in which you are laden with *an immense mass of cognition already formed, of which you cannot divest yourself if you would;* and who knows whether, if you could, you would not have made all knowledge impossible to yourself? Do you call it doubting to write down on a piece of paper that you doubt? If so, doubt has nothing to do with any serious business. But do not make believe; if pedantry has not eaten all the reality out of you, recognize, as you must, that there is much that you do not doubt, in the least. Now that which you do not at all doubt, you must and do regard as infallible, absolute truth (Hartshorne & Weiss, 1931-1935, CP 5.416).

Dewey put forth the concept of *problematic situation* (Northrup, 1947/1979, pp. 12-17) as a context for beginning an inquiry. Going back much further, the Chinese concept of the tao proposes to begin with thought of the entire universe as available to the thinker; and then to remove gradually from that universe, in a series of modest steps, only those aspects of that universe not judged to be significant in defining the scope of the investigative arena, or the problematic situation itself.

A problematic situation will normally be embedded in a larger context.

In posing a context, with an enhanced linguistic component, the following ideas are set forth.

Three Contexts

The following three contexts can be chosen for purposes of inquiry and, possibly of application: 1) The Academic Context, Higher Education (Scenario A). 2) The Global Context (Scenario B). 3) Interactions Between the Academic Context and the Global Context (Scenario C). Each of these contexts will be described separately in a brief scenario, simplified to highlight areas of special importance.

Scenario A (The academic context, higher education).

In Scenario A, there is an organization called the university (or the college). In this scenario, programmed knowledge is delivered by disciplinary practice and interdisciplinary practice.

Scenario B (The global context).

In Scenario B, most individuals are operating in several organizations (small, medium, large; family, work, state, nation, etc.), where they face many situations requiring some kind of action. Some of these situations can be dealt with by long-established practices, known to be effective in those situations. At another extreme, some of these situations are problematic, involving recourse to a wide variety of types of knowledge, some of which is not at hand and, if it were to be applied, would have to be brought to a suitable status, developed through some kind of integrative process.

Scenario C (Interaction Context).

In Scenario C, the individual strives to apply knowledge and experience in Scenario B to a problematic situation, including in the effort the choice and application of relevant resources gained while operating in Scenario A.

Operationalizing the Concept of a Unity (along lines of Foucault's thinking)

The Foucault concept of unity can be made operational across these contexts: autonomous, but not independent domains, governed by rules, but in perpetual transformation. The unities may be allied with and co-labeled with the scenarios.

The type A unities are mostly those of the disciplines, with some having been developed in interdisciplinary practice. In some instances a unity (e.g., history), often described as a social science discipline, can have interdisciplinary attributes.

The type B unities constitute a much larger class. They include beliefs incorporated in some organizational culture, e.g., religions, industrial practices, and information systems. Since Scenario B encompasses Scenario A, the type A unities are also included in the type B unities.

The type C unities are bodies of knowledge and experience that relate to how to integrate knowledge and experience from the type A- and type B-unities. In significant contrast with the type A and B unities, which are mostly content-based, type C unities are largely process-based. That is, while they have content, the content is about process.

While unities can be described as Type A (disciplinary), Type B (global), and Type C (interactive), unities can also be classified as floating, submerged, or anchored, by examining their underpinnings in formal logic. These distinctions are very relevant to knowledge integration, as will be discussed later:

1. Floating Unity. A floating unity is supported merely by a natural language, and does not contain any formalisms from formal logic. Hence its origins in logic are obscure. Social science unities usually represent this type.
2. Submerged Unity. A submerged unity is neither floating nor anchored. Its representation is a mix of natural language and *derivative formalisms*, i.e. formalisms that incorporate an anchored unity only by contextual implication, without formal expression of the anchored unity. Physical science and technological unities are almost all of this type.
3. Anchored Unity. An anchored unity is reducible to a set of formalisms from formal logic, although natural language can be used to clarify its nature.

Focus of This Paper

This paper is primarily involved with understanding what types of C-Unities (processes) are appropriate for those problematic situations in a B-Scenario (global context) which require specific attention to complexity. We will examine what is required of those processes in order to make effective the integration of knowledge (beliefs) in Type A (academic) and/or Type B (organizational, cultural, etc) unities. Secondarily, this paper is involved with explicating how floating or submerged unities can be converted to anchored unities, e.g. how natural language can be replaced with a more precise symbolic language.

For purposes of expanding on this focus, it is necessary to have an appropriate definition of the term *system*, since the act of knowledge integration involves the construction of a new system. Vickers has warned against interpreting the term system too narrowly:

> The concept of systemic relations, though not new, has been developed in the last few decades to an extent which should be welcome, since it is the key to understanding the situations in which we intervene when we exercise what initiative we have and especially to the dialectic nature of human history. It has, however, become so closely associated with man-made systems, technological design and computer science that the word 'system' is in danger of becoming unusable in the context of human history and human culture.—SIR GEOFFREY VICKERS (Vickers,1980, p. ii).

For that reason, we choose as the needed, broad definition, that of a fine and very productive American scientist. A system (following J. Willard Gibbs) is:

> any portion of the material universe which we choose to separate in thought from the rest of the universe for the purpose of considering and discussing the various changes which may occur within it under various conditions. [This definition is not widely known among systems scholars.] (Rukeyser, 1988, p. 235).

At this point, it is possible to summarize briefly a platform from which continuing movement in inquiry seems to be justified, as shown in Table 1.

Table 1

Building A Platform For Initiating Inquiry	
Operating Concept	**Higher-Level Umbrella Term**
Problem	Problematic Situation
Discipline	Unity
Academic	Global
Interdisciplinary	Unity
Topical Area	System
Prose	Combined Prose and Graphics

The Most Essential Product of Successful Integrative Studies Should Be A Structured (Qualitative) System Model

Human Knowledge

All human knowledge is constructed by human beings as collections of models, formal, informal, or hybrid (a mixture of formal and informal) from origins in individual belief. Consequently, in elevating belief to the status of knowledge, integration is essential. If the integration acknowledges, in its practice, that models are being built through integration, the possibility of drawing on some advantages of formalisms for integration comes into view. Formal models are numerant, structural, or hybrid (a mixture of numerant and structural). Structural models are linear or nonlinear. A linear structural model is isomorphic to a directed graph, so that a directed line can be drawn passing through all vertexes and lines without touching any more than once.

Model Spaces

Model Spaces are formal and mathematical (heavily symbolic and programmable) of three major types: root, intermediate, and application-oriented. A *root space* is a mathematical space that forms a comprehensive framework for developing and positioning a formal model, as distinguished from any of its submodels. An *intermediate space* is like a root space, but serves only for proper submodels, and may not be generalizable to the parent models. An *application- oriented space* typically is idiosyncratic to a particular, narrow-context application and, quite frequently, is very poorly suited to extension into lateral or more inclusive domains. But, as Hayek said, that does not prevent such extensions from being carried out:

> During the first half of the nineteenth century a new attitude made its appearance. The term science came more and more to be confined to the physical and biological disciplines which at the same time began to claim for themselves a special rigorousness and certainty which distinguished them from all others. Their success was such that they soon came to exercise an extraordinary fascination on those working in other fields, who rapidly began to imitate their teaching and vocabulary. Thus the tyranny commenced, which the methods and technique of the sciences in the narrow sense of the term, have ever since exercised over the other subjects (Hayek, 1955, pp. 20-21).

The Situation

Amelioration of undesired consequences of complexity involves the study of situations and systems. A *situation* (the shorter view of the term problematic situation) is a triad consisting of (a) a human component (an individual or an aggregation of individuals), (b) other systems contained in the situation, and (c) their respective environments. A *universe* is a set of all situations relevant to a chosen investigation.

Models of Complexity Furnish Learning Opportunities

In his justly-famous paper published in 1878, titled “How to Make our Ideas Clear,” Charles Sanders Peirce talked about false distinctions that are sometimes made in assessing beliefs. Of relevance to situations involving complexity, he wrote the following:

> One singular deception...which often occurs, is to mistake the sensation produced by our own unclearness of thought for a character of the object we are thinking. Instead of perceiving that the obscurity is purely subjective, we fancy that we contemplate a quality of the object which is essentially mysterious....So long as this deception lasts, it obviously puts an impassable barrier in the way of perspicuous thinking; so that it

> equally interests the opponents of rational thought to perpetuate it, and its adherents to guard against it (Peirce, 1878/1991, p.168).

This idea can be paraphrased somewhat, and turned into a definition of Complexity.

First of all, it is surely true that the vast majority of modern thought about complexity perceives it to be a property of what is being observed, instead of being a subjective response to the not-understood. The language itself clearly demonstrates this, in the common use of terms such as complex system, and complex problem.

Yet it is easy to imagine this: if the human being had the mental power to comprehend everything that was of any interest, there would be no such thing as a complex system or complex problem in the usual sense, or of complexity in the sense discussed here. Clearly then, the very existence of complexity is directly connected to human mental limitations. *Complexity is not a property of what is being observed, but rather is a sensation arising out of our own unclearness of thought, when we are engaged with what we are observing* (Miller, 1956, Simon, 1974, Warfield, 1988).

While this definition may be thought surprising, one of its notable attributes is that it allows for the possibility that complexity may be reduced or even eliminated, by a process called Learning. When or if our models of complexity fail to inspire confidence, perhaps it is often because of what is not said in the models.

The late contemporary French philosopher and chairman of the history of systems of thought at the Collège de France, Michel Foucault (1926-1984) in his masterful discussion of the archaeology of knowledge, stated

> the manifest discourse, therefore, is really no more than the repressive presence of what it does not say; and this 'not-said' is a hollow that undermines from within all that is said (Foucault, 1993, p. 125).

And perhaps the reasons for the not-said include both lack of comprehension, and undue addiction to inadequate modes of *representation* of complexity.

Integrative Studies Must Take Complexity Into Account Overtly

A prolonged period of research on complexity has surfaced *only seven* means of representation that are scale-independent, and provide the opportunity to portray visually the total, integrated, current comprehension of a situation. None of these representation methods is observable in publications by most scholars of integrative studies. Because of the sparseness of the array of modes of representation of complexity, integrative studies should become amenable to choosing, from the seven modes, those that are particularly relevant to a situation. The seven modes are:

1. Arrow-bullet diagrams (which are mappable from square binary matrices, and which correspond to digraphs).
2. Element-relation diagrams (which are mappable from incidence matrices, and which correspond to bipartite relations).
3. Fields (which are mappable from multiple, square binary matrices, which correspond to multiple digraphs, and which may be extended into Tapestries).
4. Profiles (which correspond to multiple binary vectors, and also correspond to Boolean spaces).
5. Total inclusion structures (which correspond to distributive lattices and to power sets of a given basis set).
6. Partition structures (which correspond to the non-distributive lattices of all partitions of a basis set).
7. DELTA charts (which are restricted to use with temporal relationships, and which sacrifice direct mathematical connections to versatility in applications).

These various structural types (which are discussed extensively in the references) reflect two necessities:

1. Overt modal choice. The necessity to choose modes of representation that are adequate to portray complexity in learning situations.
2. Resort to formalism. The necessity to define these modes in terms of established branches of mathematics, in order to clarify what they are, and in order to take advantage of the principles of mathematical operations upon large information sets, including large numbers of relationships.

While there is no escaping these two necessities, two unfortunate consequences ensue when they are accepted:

1. Learning time must be allocated. It is necessary to spend a significant amount of time in developing the representations; more than academics will normally dedicate, especially in group settings, given the current institutional, architectural infrastructure.
2. The superficial must be consciously foregone. People who lack the mathematical understanding of the foundations beneath these modes of representation have a tendency to take the easy way out and resort to unsupported superficialities, e.g., to William James' "higher genus" (James, W. P. pp 55-56).

The first of these consequences can be ameliorated by efficient group learning processes, supported by adequate spatial infrastructures. The second can be ameliorated by transferring the mathematical burden to the computer; an act which also greatly enhances the efficacy of the group processes. Both of these requirements for amelioration are now adequately understood, tested, and documented for purposes of application in long-standing or envisaged situations.

The central conclusion is that, in order to cope adequately with complexity, it is necessary, in its overt recognition, to apply well-designed and tested processes of the form documented under the rubric Interactive Management (Warfield & Cárdenas, 1994, Warfield, 1994). Fortunately these processes, like the formalisms themselves, can be effective in working with any of the unities.

The Sciences Furnish a Test Bed For Integrative Studies

Integrative studies are broadly inclusive in scope, encompassing the sciences, the humanities, and the professions. Each of these areas has its own distinctive cultural features and educational concerns. Rather than attempt to articulate integrative studies across the board, this paper will limit more detailed attention to the sciences, with the belief that what is discussed in that context will be transferable in some ways, at least, to the other areas. Even to accomplish this, it is necessary to rethink science from the perspective of requirements for integration.

Science

A science is a body of evolving belief consisting of three variously-integrated components: foundations, theory, and methodology. (This definition is not generally known inside or outside the systems arena, whether academic or practicing.) Foundations inform the theory and the theory informs the methodology. The volume of approved knowledge is smallest in the foundations and largest in the methodology. The domain of a science consists of the science and its applications. All science is evolutionary. Evolution typically occurs by comparing the congruence between the science and results observed in its applications. Sciences can be generally described as falling into one of two major categories: *descriptive science* and *normative science*. To appreciate the distinctions, it is necessary to expand older conceptualizations of what science is. To do otherwise is to limit science to a purely descriptive role; instead of accommodating to the larger role of applying its descriptions to help resolve complexity in today's world. The two categories of normative and descriptive science are integrated in the Work Program of Complexity.

The Work Program of Complexity

The Work Program of Complexity makes up the horizontal side of a matrix. The vertical side is the Behavioral Menu. Each of the sixteen cells in the Behavior—Outcomes Matrix shown in Figure 1 is a unique area of study that can be supported by scientific knowledge. Those cells which contain items show the names of one or more of the 20 Laws of Complexity (Warfield, 1999). The articulation of the Laws has evolved slowly over a period of more than twenty years.

The Work Program (across the top) reflects four activities: Description, Diagnosis, Design, and Implementation. Of these four, Description reflects the conventional view of science, i.e., descriptive science. Diagnosis may have both a descriptive and a normative science underpinning. Design, based on the Description and Diagnosis; and Implementation, as well; both reflect possibilities for applying normative science.

Descriptive science.

Descriptive science involves the creation of a sharable language directly applicable to relatively precise delineation of a situation, along with the conduct and analysis of a sufficient number of observations to make possible an adequate description of the situation. As mentioned previously, for situations involving complexity, only seven descriptional modes have been determined so far to be adequate for representations.

Figure 1

OUTCOMES				
Behavior	**Description**	**Diagnosis**	**Prescription (Design)**	**Implementation**
Process	• Limits • Triadic Necessity & Sufficiency • Universal Priors	• Sucess & Failure • Universal Priors		• Gradation • Validation
Individual	• Limits • Triadic Compatibility • Small Displays		• Requisite Parsimony • Requisite Saliency	
Group	• Limits • Uncorrelated Extremes	• Inherent Conflict • Structural Underconceptualization • Diverse Beliefs	• Requisite Variety • Induced Groupthink	
Organizational	• Limits • Organizational Linguistics • Vertical Incoherence	• Forced Substitution • Precluded Resolution • Vertical Incoherence		

Normative science.

Of the many relevant discussions of science, one may note those related to the normative sciences. The view of Charles Sanders Peirce, an outstanding scientist and logician, is described by Potter as follows:

> ...*logical inquiry* is (for Peirce, at least) one of three normative sciences whose character is ultimately comprehensible only in reference to the two other normative sciences *esthetics*, conceived as the investigation of ultimate ends, and *ethics*, conceived as the investigation of self-controlled conduct [italics added] (Potter, 1996, p. xviii).

The processes of Interactive Management accommodate both descriptive and normative science. They do so by providing computerized assistance in coping with the logical inquiry, while providing ample opportunity for those engaged in the inquiry to apply their sense of ethics and esthetics in the decisions made in Diagnosis, Design, and Implementation.

For this to be possible, the processes must reflect a thorough study of human behavior in carrying out such activity, and must provide corrective means to overcome both (a) the well-known limitations on individuals in working with information, and (b) the less well-known, but adequately described, group pathologies that limit groups in working with information.

Formalisms Provide a Strong Basis For Anchoring Integrative Studies

Formal languages and the formalisms that they represent provide a strong basis for anchoring integrative studies. To realize this, one needs a new image of the constituents of the argument:

Formal Language

FORMAL LANGUAGE: An uninterpreted system of signs. The signs are typically of three sorts: (1) *variables* , for example, sentence letters p, q, r, s; (2) *connectives*, for example, _, &, ø, by which signs are joined together; and (3) *punctuation devices*, such as brackets, to remove ambiguity. There are also *formation rules* telling how to string signs together to form well-formed formulae, and *transformation rules* telling how to transform one string of signs into another.

Formal languages in this sense are just sets of marks permutable by rules, much as chess notation is. They may, however, be interpreted. Thus if (1) the variable letters are made to stand for propositions, (2) _, &, ø to stand for ‘or’, ‘and’, and ‘if—then’ and (3) the transformation rules are made deduction rules, then *the formal language has been interpreted as a system of logic*.

Distinction must be made between formal languages (uninterpreted systems of marks) and artificial languages (interpreted formal languages which are, however, not natural languages as vernacular English is). ANTHONY FLEW, *A Dictionary of Philosophy* (Flew, 1984, pp.123-124).

Subsumption

A critical aspect of the organization of knowledge is the act of subsuming. Subsuming connects two concepts through their relative positions in the development of an artificial language:

If we represent *is subsumed within* by *sub*,
then "A sub B" means that A is contained within B,
i.e., subsumed within B.

Supersumption

Not generally viewed as an operation, but open to critique nonetheless, is the converse concept, which could be written as

"B sup A" meaning that B supersumes A,
i.e., that B encompasses A
hence, as stated before, that "A sub B."

But unfortunately, in the academic turf game and in some high-stakes consulting operations, the relationship is sometimes reversed whether by design or by mistake. That is, even though "A sub B," it will be implied, possibly in order to market a concept, that "A sup B" (yielding the implication that the component is superior to its enclosure); a piece of faulty logic that defies reason. Such malfeasance in reasoning is readily put to death if formalisms are responsibly applied and made easily understandable by the use of well-defined prose-graphics language.

Formalism

> FORMALISM 1. (mathematics) A view pioneered by D. Hilbert (1862-1943) and his followers, in which it was claimed that the only foundation necessary for mathematics is its formalization and the proof that the system produced is consistent. Numbers (and formulae and proofs) were regarded merely as sequences of strokes, not as objects denoted by such strokes. Hilbert's programme was to put mathematics on a sound footing by reducing it (via arithmetic) to consistent axioms and deriva tion rules, the former being certain series of strokes, the latter ways of

> manipulating them. Later Gödel showed that the consistency of arithmetic cannot be proved within the system itself, thus demonstrating the impossibility of achieving part of the Hilbert programme. 2. (in ethics and aesthetics) Emphasis on formal issues at the expense of content. The term is generally employed by opponents of such atti tudes.—ANTHONY FLEW, *A Dictionary of Philosophy* (Flew, 1984, p. 123).

Derivative Formalism

Sometimes a type of formalism is involved which appears at first glance to be a natural language in use, but is actually a careful construction of language as equivalent to mathematical or logical symbol, e.g. incorporation of an anchored unity only by contextual implication, without formal expression of the anchored unity.

Steps in Applying a Formalism

Formalisms are available to unities at their beck and call. But the use of a formalism as a way of representing some aspect of a unity can be described normatively as follows:

Step 1. Selecting a unity. Select a unity for which a choice of formalisms might be appropriate to represent complexity.

Step 2. Identifying a relevant formalism. Identify a particular formalism whose construction is compatible with the descriptive requirements of the chosen unity.

Step 3. Making concept associations. Make associations of specific concepts from the unity with specific symbols in the formalism [a step in converting the formalism from its inherent non-interpretive state (see the excerpt from Flew given above) to an interpretive state].

Step 4. Making relationship associations. Make associations among those chosen concepts with particular relationship types, in order to enable relationships to be interpreted.

Step 5. Selecting a consistency test. If consistency is admired, use any available consistency test from the chosen formalism or, if the chosen formalism has none, select a formalism that does have one, and which is compatible with the formalism chosen earlier.

Step 6. Constructing a language. Solidify the presentation into an *artificial* or *object* language.

Step 7. Assigning numerical values. If it is desired that concepts in the new language should be numerically quantified, assign numerical values to the appropriate concepts. (It may be necessary to carry out experiments in order to determine numerical assignments.)

Association

Having just used the word *association*, it is best now to specify exactly what it means. When making an association, a concept of interest in the chosen unity is paired uniquely with a particular symbol from the formalism. If, for example, the formalism includes the symbol $\underline{x}$, and if the unity involves *electrical current*, one may make an association between the symbol $\underline{x}$ and the electrical current. One may (and usually does) make a prior association involving a new symbol, such as $\underline{I}$, so that there is really a double association:

$$\underline{x} \leftrightarrow \underline{I}, \qquad \underline{I} \leftrightarrow \text{electrical current}$$

When this is done, it is usually done en masse, so that, whatever symbolism may have been chosen to present the formalism, that symbolism may be replaced in totality with a new symbolism. The link between the interpretive term, such as electrical current, with the original formalism may then be lost in deference to the revised symbolism particular to a specific unity. This loss of link tends to invoke the culture of the unity and serves, as well, to distance that culture from the original formalism. While this is very convenient in applications of the unity, it tends to mask the debt which the unity owes to the originators of the formalism and may, over time, obscure the connection with the formalism. If that occurs, some consorts of the unity may even depart from the formalism without notification, thereby losing the structural and substantive integrity which (one hopes) was present in the chosen formalism.

Associations may be most powerful when they involve the Theory of Relations as the formalism. This is because the Theory of Relations, as implemented in the computer-assisted process called Interpretive Structural Modeling, can be applied to give major help to people who are interested in a careful organization or reorganization of existing unities. Associations are prominent and overt, and apply both to the elements and to the relationships.

Assignment

The formalism can be seen as the broadest type of non-interpretable unity. It is essential that this type *not* be interpretable (in Flew's sense), in order that associations can be made to convert this type of unity into interpretable form. This is precisely the key to interdisciplinary integration. As soon as a set of associations is complete, we have an artificial unity, which is narrower in scope of application than the formalism. Still, the artificial unity has some generality, because it is not restricted to particular numerical values.

Assignment can be carried out following association. Assignment refers to the attachment of a numerical value to an association or, more generally, the assignment of a set of values to a set of associations. We must keep in mind, when making assignments, that the set of associations is tantamount to a set of constraints on allowable assignments. So, for example, if we have a formula like $\underline{I} = \underline{E/R}$ among a set of associations, we can only assign to two of the three components in that formula; whereupon the third one is determined.

The passage from formalism to association to assignment is a passage from the very general to the very specific. This is the kind of passage that underpins applications of science to the so-called real world. When the passage is denied or ignored, by lopping off any reference to the formalism (as the chaos theorists and adaptive systems theorists, among others, are likely to do), we have a kind of "sin against science" which characterizes, for example, much of the U. S. scientific and technological society. Being a very inventive society, with strong attachment to independent behavior, there is a large reluctance even to retrace thought to the formalisms, much less to be disciplined by them, except in instances where there is a long history of adherence; in which the rare, but occasional, allegiance to a formalism is a habit of long standing.

When are association and assignment justified?

The justification of association and assignment to a formalism comes about in at least two possible ways: 1) As the instantiation of a hypothesis that is going to be tested. 2) As the solidification of an adequate body of empirical evidence. Both of these are critical components of integrative studies, as seen most sharply when considering *integration of sciences*.

What is meant by integration of sciences?

This is a phrase that may be tossed about lightly, without strict meaning. However, it can be given a rather strict meaning, if it is seen in the light of the Domain of Science Model.

What is the Domain of Science Model (DOSM)?

The Domain of Science Model (DOSM) is a reentrant graphics model. It portrays a science as a body of knowledge arrayed in three parts:
1) Foundations. 2) Theory. 3) Methodology. In this reentrant model, all of whose components are subject to revision in the light of new discoveries in the relevant domain,

$$\text{Foundations} \Rightarrow \text{Theory} \Rightarrow \text{Methodology} \Rightarrow \text{Applications} \Rightarrow \text{Foundations.}$$

where the arrow represents this relationship: *inform(s)*.

Through the relationship among the components, every part of the model is related to every other part of the model. In terms of size of presentation, the Foundations form the smallest part, the Theory forms a larger part, and the Methodology forms a still larger part.

Integration of sciences is best accomplished by integrating at the level of the Foundations, and then proceeding to integrate the Theory according to the discipline imposed by the integration of the Foundations. After the Foundations and Theory are integrated, one can proceed to integrate the Methodologies. This process is indefinitely iterative, and dealt with flexibly.

For most established sciences, the part of the Domain of Science Model that involves Applications can be very small. To be included in the DOSM of a science, it must be true that *only that science is required for applications.* But most applications of science can benefit from or even require an integration of sciences. For this reason, those sciences that represent the integration of several sciences often have much larger Applications components than the individual component sciences.

Unfortunately, there is only one science that today is overtly organized according to the DOSM (i.e., makes clear which is which among the three components). That is the *science of generic design* (Warfield, 1994). It is so organized, because the DOSM was used to discipline the creation of that science.

Perhaps, some day, denizens of more established sciences will understand the need and benefit of reorganizing those sciences to reflect the personal discipline imposed by following the DOSM. In this respect, Michel Foucault can be seen as the creator of the imperatives and some of the language for carrying out such an adventure. In his *The Archaeology of Knowledge*, as reflected in A. M. Sheridan Smith's translation, Foucault describes this view of reconstitution:

> the reconstitution, on the basis of what the documents say, and sometimes merely hint at, of the past from which they emanate and which has now disappeared far behind them...[and on the basis of] transformations that serve as new foundations, the rebuilding of foundations (Foucault, 1993, pp. 6,5).

And later, in striving to define more precisely what is meant by his term "archaeology of knowledge," Foucault says: "It is an attempt to define a particular site by the exteriority of its vicinity; rather than trying to reduce others to silence, by claiming that what they say is worthless" (Foucault, 1993, p. 17).

The definition of a particular site in science, can be carried out through the reconstitution of the science, as disciplined by the DOSM. And when that is done the exteriority of its vicinity can be enlarged if adjacent or proximity sciences, or overlapping sciences, can themselves be so reconstituted. Until that occurs, relatively slow evolution of applications of integrative sciences can be confidently predicted.

Some examples of this activity appear in Tables 2, 3, and 4. For each instance, and generally, all of the formalisms that are part of the chosen formal language (mathematical system) can be applied in working with aggregates.

Table 2

Formalisms As The Basis For Applying Science
First Example: Physics, Electricity
1. Choose the appropriate formalism from the many available in mathematics.
2. The Chosen Formalism: $x = y/z$
3. Make Associations: $I = E/R$
4. Make Assignments: $E = 100$, $R = 10$
5. Compute Inference: $I = 10$

Table 3

Formalisms As The Basis For Applying Science
Second Example: Situational Definition
1. Choose the appropriate formalism from the many available in mathematics.
2. The Chosen Formalism: Set theory; set operations, membership, inclusion, union, disjunction, Cartesian products of all orders; lattice isomorphisms.
3 and 4 combined. Make Associations and Assignments: Identify key situational set types and relationship types. Give them symbolic names and application names.
5. Compute Inference: Not required in definitional algorithms.

Table 4

Formalisms As The Basis For Applying Science

Third Example: Computation of Structure

1. Choose the appropriate formalism from the many available in mathematics.

2. The chosen formalism: $a_iRb_j = s_{I,j}$;
$M^2 = M$; M a binary matrix;
Matrix operation is Boolean.

3. Make Associations: Problem i; Problem j; significantly aggravate; Connection Digraph.

4. Make Assignments: Does problem i aggravate problem j?
$s_{ij} = 0$, “no”; = 1, “yes”

5. Compute Inference:
$s_{ij} = 1$ and $s_{jk} = 1$, implies $s_{ik} = 1$; as basis for matrix operations.

The Organization Is the Action Venue

Because of the heavy demands for cooperative group activity in working with complexity, it is natural that the organization should be the venue for the work.

Complexity Reduction Through Structural Thinking

To illustrate how the fourth component (organizations) of the Behavioral Menu in Figure 1 is dealt with, two examples of the application of the Structure-Based School approach to resolving complexity will be presented. The first example is illustrated by experience with redesign of the U. S. Defense Acquisition System, using design and process contributions from the Structure-Based School (Warfield & Staley, 1996).

Table 5 describes three levels in a vertically-integrated (inclusion) structure relevant to the problematic situation. The three levels are here

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described as the Operational Level, the Tactical Level, and the Strategic Level. These names are chosen to reflect somewhat standard usage in the management of large organizations. This 3-level pattern is called The Alberts Pattern after its discoverer, Professor Henry Alberts (Alberts, 1995). A similar pattern, differing only in the numerical data, was independently found in a systems engineering curriculum study in Mexico (Cárdenas & Rivas, 1995). Notably, the higher genus is included here, but only as the overarching component; while extensive detail at lower levels in the hierarchy of information amplifies and elucidates the higher levels.

In the Operational Level, as indicated in Table 5, 678 problems relative to system acquisition were collectively identified (by more than 300 program managers who were active in defense acquisition management). In the Tactical Level, these 678 problems were placed in 20 tactical categories. Finally, in the Strategic Level, these 20 categories were placed in 6 strategic domains.

Table 5

Two Examples Of The Alberts Pattern in Organizations

Organization	Number of Elements (Operational Level)	Number of Element Categories (Tactical Level)	Number of Element Domains (Strategic Level)
U.S. Defense Acquisition System	678 problems	20 problem categories	6 problem domains
Instituto Tecnologico y de Estudios Superiores de Monterrey – Industrial and Systems Engineering	270 design options	20 design option categories	4 design option domains

In his dissertation, Professor Alberts indicated that one of the two main objectives of his work was to use that work to represent a prototype process for organizational redesign, an extensive application of a designed process for reducing complexity. Complexity was reduced dramatically as the work progressed through the three levels. When completed, a highly transparent representation of the acquisition system was available. This allowed persons in the operational aspects of acquisition to relate the problems they work with every day to the higher-level categories; and vice versa. As a result, a redesign of the system could be carried out that reflected high visual capability in connecting design options to problems at all three levels. It is very likely that because of this extensive referential transparency, the relevant legislation passed by the U. S. Congress involved only minimal modification to the results coming from this work. The legislation, identified as Public Law 103-355, October 13, 1994, is cited as the *Federal Acquisition Streamlining Act of 1994*.

A similar reduction in complexity occurred in the Mexican work. By developing the capacity to work back and forth among the three levels of the inclusion structure, from the very specific, to the general oversight areas, a coherent insight and correspondingly coherent approach to effective management of what had been relatively unmanageable becomes very feasible (Warfield & Staley, 1996).

The Lasswell Triad

The possibility of broad-based learning about very large systems becomes more realistic when what is called here The Lasswell Triad is understood. Harold Lasswell (1902-1978) was a political scientist, one of the foremost authorities in that field. As a faculty member, he taught law and political science at the University of Chicago, Yale, and elsewhere. Author of many books and papers, he originated key ideas relevant to the effective design and understanding of public policy, which remain essentially dormant today.

His view on policy making is that our traditional patterns of problem-solving are flagrantly defective in presenting the future in ways that contribute insight and understanding. The Lasswell Triad is responsive to this view, in part. It consists of these three concepts: (a) “Decision Seminar [taking place in a specially-designed facility],” (b) “Social Planetarium,” and (c) “Prelegislatures” (Lasswell, 1963, p. 125, p. 140, p. 142). In brief, here are his key ideas involved in this Triad:

The situation room.

First, a special facility needs to be put in place, where people can work together on design of complex policy (or other) issues, and where the display facilities have been carefully designed into the facility, so that they provide prominent ways for the participants to work with the future.

The prelegislature.

Second, this special facility should be used extensively to develop high-quality designs long before legislatures or corporate bodies ever meet to try to resolve some complex issue facing them by designing a new system (e.g., this is a sensible way to go about designing a health-care system to which the political establishment can repair for insights and such modifications as seem essential).

The observatorium.

Once the design has been accepted, the observatorium is designed and established so that people can walk through a sequential learning experience, in which they gain both an overview and an in-depth understanding of the system that has been designed and which, most likely, will be prominent in their own lives.

The observatorium is a piece of real estate, whose building interior can be loosely compared with that of the Louvre, in that it contains a variety of rooms, and facilitates rapid familiarization with their contents by the persons who walk through that property. Further analogy comes from the recognition of the importance of wall displays (with electronic adjuncts), large enough in size to preclude any necessity to truncate communications; and tailored to help eradicate or minimize complexity in understanding, both broadly and in depth, the nature of the large organization; its problems, its vision, and its ongoing efforts to resolve its difficulties. Comparison with the planetarium for envisaging a broad swatch of the sky is self-evident.

The descriptions just given represent only modest deviations from the Lasswell Triad, but slight changes in nomenclature have been adopted for purposes of this paper. Given that relatively little has been done with the Lasswell Triad, two questions might arise. The first might be: Why? Another might be: *Are there additions that have to be made that, when* *integrated with the Lasswell Triad, provide a practical means for enhancing greatly the design, management, amendment, and understanding of large, complex systems?* This last question will now be answered: Yes.

No one would expect that the observatorium would be brought into place unless the displays required to fill it were available, and if the topic were of vital social importance. It would, therefore, be important to have conceived and created the situation room required for effective group work, and to have conducted the necessary prelegislative activity to provide the raw display information for the observatorium.

A situation room of the type desired was developed in 1980, and has since been put into place in a variety of locations (Warfield, 1994). Rooms of this type provided the environment for the Alberts work, and for many other applications of Interactive Management (Warfield & Cárdenas, 1994). Thus the first essential preparation for the observatorium is complete. The Alberts application, and other ongoing applications have and are providing the second essential raw display information.

What kinds of displays are required for the observatorium? These displays must meet stringent communication requirements. In brief, they must meet the demands of complexity for effective representation. This means, among other things, that they must be large, and they must cater to human cognitive requirements. At present, the displays will be chosen from the seven modes described earlier in this paper.

With the identification of the Lasswell Triad as the type of infrastructural invention required to deal comprehensively with complexity, hence with knowledge integration, the Good Assumptions presented earlier in this paper have been amplified to show the requirements of good practice, as dictated by complexity.

The Last Word

An effort has been made, in this paper, to emphasize the necessity and feasibility of basing integrative studies on formalisms. The principal arguments in support of this idea basically reduce to conditions for adequate use of language by fallible human beings. Still, there will be those who will feel the necessity of rejecting both the proposal and the rationale for it.

There are some substantive reasons to reject this proposal. One good reason to reject it is that, even if it seems meritorious, there is no reason to suppose that it will be properly implemented by practitioners.

The Prose-Crustes Practitioners

The age-old story of the giant Procrustes, who fit every traveler to accommodate his bed, either by stretching the traveler or lopping off parts, applies to insisting on associating perception and description only with prose. There are those who wish to represent everything exclusively in prose, or perhaps in prose augmented by computer-generated artwork. There are certainly instances where such representations are very appropriate, but they tend to be limited to fiction and/or entertainment; rather than domains where substantive integration of substantive knowledge components is desired.

The Narrow-Circle Technocrat

The narrow-circle technocrat wishes to make representations mostly in either mathematics or floating graphics or a combination thereof. The effect of this is generally to inhibit communication, or close it off altogether, but it does often have the effect of protecting the "rice bowl."

The Procrustean behavior is present there as well. The narrow-circle technocrat often makes a very poor choice of formalism from which to create a set of associations. The operational features of a formalism are adopted and often heavily promoted, but without satisfying the axiomatic basis of the formalism as a necessary condition for its selection and use. For example, some use "systems dynamics" for representing very wide-scope situations., when there is no evidence that such situations satisfy the axiomatic conditions required to apply the (non-interpretable) formalism. This practice gives formalisms a bad name and provides reinforcement to those who want to shun formalisms.

The Odd Couple

Because of the Procrustean behavior that is shared by the prose-minded individual (typically with a liberal arts-orientation) and the technocrat (typically with an engineering, business, or applied-science orientation); these two groups, in effect, collaborate as an unofficial cartel to work (perhaps unknowingly) against effective communication.

The Inherent Difficulty

Without regard to the cultural features of persons who populate a unity, one can say that there is an inherent difficulty in creating an adequate, understandable structural basis for a unity. If it were not so, the unities would be much better understood than they are at present. All it takes to deny an adequate representation of a unity is this inherent difficulty, accompanied by even a modest adherence to representation in the ordinary communication vehicles of the genre.

Faced with this situation, the most powerful argument that can be brought to support the proposals advanced here may be that the ease of integrating two sciences is greatest at the level of the foundations, where opportunities for inconsistency and error are the least, because of the very small population of foundational ideas. And the available technological support for doing such integration in the complex, problematic situations is demonstrably effective.

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