THREE DOMAINS OF COMPLEXITY
John N. Warfield

ABSTRACT

A research study extending over more than 30 years has identified three "Domains of Complexity. They are identified as follows:

- **Domain 1: The Basic Relationship Fields**, the main purpose being to show categories from which types of relationships, and members of selected types, can be chosen for purposes of model construction in particular situations, including especially structural models. A secondary purpose is to support the idea of giving the choice of relationship types an emphasis equivalent to that given to the choice of elements to be related.

- **Domain 2: The Basic Element Fields and Areas**, the purpose being to show how empirical work has produced a set of categories whose contents support the development and application of a science of complexity, based in structural and behavioral considerations.

- **Domain 3: The Program Domain**, with three sub-domains, whose purposes are to provide learning materials suitable for particular modes of delivery and particular audiences. One of these sub-domains, the Work Program of Complexity; emphasizes tested, practical modes for resolving complexity in organizations.

Following the developments in Domain 2, three content analyses were used to cross-check the discoveries of the basic element fields and areas. These analyses tended to confirm the discoveries in Domain 2.

The three program sub-domains in Domain 3 represent different types of activities related to the teaching or application of the ideas stemming from the research.

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The concept of "categories" is found in the writings of Aristotle, more than two thousand years ago. His idea was that everything in the universe could be placed in one of a small number of categories, which he enunciated. His ideas are carried forward through a joint project between Oxford University and Harvard University, and can be found in a published book of his writings[1].

The concept of category is both substantive and structural in nature. Categories are based on the relationship "is included in". So, if A is included in B, then B is a category which includes A. When the structural nature of categories is seen in this way, it is a short step to realize that more than two levels of structure will usually be involved. So if A is included in B, and B is included in C, then C is a category for both A and B. This idea can be extended to include more than three levels. The idea is usually introduced with Venn Diagrams, but its multilevel extension is facilitated by use of digraph-like structures.

It is tempting to say that all concepts necessarily lie in an inclusion hierarchy, some members being at the lowest level, others lying at higher levels, until finally one supposes there is one master category that is all embracing (such as "the universe" or "God"). For structural reasons, this temptation must be amended to be most useful.

Even if nature has provided hierarchies, man has greatly weakened the *conversational utility* of the term. Because of synonyms in linguistics, and in the interests of completeness, one may wish to say that A is included in B and B is included in A. This form of relationship is called a "cycle"[2]. If conversations of discovery are to be allowed, it is necessary to allow cyclic expressions, hence the structure of concepts is to be regarded as comprised of hierarchical and cyclic components. If these distinctions seem strange, one may find them less strange through the realization that (a) categories are sets (b) sets are governed by the theory of relations, and (c) both set theory and the theory of relations thrive when they exhibit completeness of thought, enabling them to take part in computerized activities which help people organize things[3] [x].

Even if there is a single overarching structure, conversations typically relate only to a few substructures. Typically conversations never sort out or incorporate all of the relevant substructures. Attempts to do so in ordinary conversation would flounder for lack of time and for lack of adequate cognitive capacity. Also there is

no reason to suppose that any two human beings perceive intuitively the same substructures except, perhaps, in the simplest situations. Hence the quality of conventional dialog can hardly be expected to be high, except in the simplest situations. This is one of the reasons why legislative bodies so often construct legislation that does not incorporate elements essential to achieving stated goals of the legislation[4]. Similarly, executives often cannot articulate truthfully because the oral language does not permit necessary structure to be shown. As a result, executives often are mistrusted, or get by on charm instead of substance. Conversationally constructed system designs that could have benefited from thorough connections to the logic of relations display gaping weaknesses when transformed into actions[5] [x].

It is unlikely that a category would have been useful, or even conceived, at least initially when the world was young, without noticing the presence of elements that deserved to be placed in the same category. It seems reasonable to suppose that rules were conceived, intuitively or openly, whereby two things were thought to warrant placement in the same category.

In the absence of perfect cloning, it seems reasonable to suppose that rules for placing things in the same category would not be so stringent as to require that, in order for distinguishable X and Y to go in the same category, they would have to have everything in common. Instead it is easy to suppose that there would be some minimum correlation required, some minimum set of attributes that would be shared in order to be placed in the same category. If that be true, there would likely be some core set of attributes which each element of a certain category would own; but each member could then have one or more additional attributes not shared by all members of the category. This reasoning was known by Aristotle, using the language of essences and accidents, and it remains true today.

But this core set might have to be altered if a new member were proposed for reasons of convenience, and that new member did not share all of the core attributes. The idea that categories can readily be accepted and frozen, while perhaps supported by appearances in practice, is not supported by careful reasoning. Thus if it is desired to construct a set of categories that might have extended life, the most careful and prolonged study seems to be appropriate. Even then, a claim for uniqueness is unlikely to be convincing, utility notwithstanding.

Today, however, categories are often created first, then things are fitted into those chosen categories, much as the ancient giant Procrustes fitted travelers into the bed in his wayside inn. For example, arbitrarily-created categories are ensconced in

organizations, and people are placed in them. This top-down approach to categorization has been described as "hardening of the categories". Categories then often become the principal descriptor of the individual. Instead of being attuned to see the individual as distinct, he/she becomes a member of a category.

Such behavior is both expeditious and reflective of human cognitive shortcomings. If it were possible to maintain constant cognizance of all the factors that make up a human being or other entity, there would be no *necessity* to place human beings expeditiously in categories. There might, however, still be reasons to do so. Michel Foucault has identified types of "dividing practices"[6] [x]. These are practices that have the effect of differentiating groups of individuals, of placing individuals in categories.

These dividing practices seemingly can serve more than one purpose. One of the purposes is political. By identifying groups, it is possible to play one group against another for political gain or, as Foucault might say it, in order to gain power over those groups. Another of the purposes might be personal. An individual who seeks personal identity might find it valuable to self-assign categories. Some categories arise out of scientific study, or simple observation (which, in the simplest instances, can emulate scientific study; e.g., a person may be placed in the category "black" because of a black visage, or because of certain tests with skin pigments). Often when people are placed in such categories, they may take it for granted that those categories truly represent them, and after that they may be subject to group manipulation by their own self-appointed leaders or by political parties.

Long-extant categories may lose their original meanings but persist nonetheless. American universities retain such designations as "assistant professor", "associate professor", etc., even though British universities seem to get along fine without this set of categories (though they have their own). One wonders how significant such categories can be if, given two sets of universities, one set uses one and another set uses the other, and both seem to survive. Meaningless categories in widespread use frustrate insightful discussions about redesign or reform.

How can one reform an organization when its commonly-accepted very descriptive terms elude reason?

The possibility of organizational reform that begins with language is not new. Lavoisier is quoted as having said that when he started (from his education as a lawyer, a field where painstaking linguistics seems critical) to study chemistry, his

first goal was just to improve the language of the subject. And having chosen to pursue that goal, he was drawn into the reformation of the entire subject. Such is the importance of the choices of categories.

Nomenclature. To facilitate the ensuing discussion, a nomenclature that is responsive to the structural aspects of complexity and to the structural aspects of categories has been chosen. The most basic components are twofold. They are called *elements* and *relationships*[7].

A *category* is defined as a set whose members are specified by virtue of an assessment that the members have significant features in common. A *field* is defined as a category whose members are comprised of either elements or relationships (but not of both). An *area* is a category whose members are *fields*. A *domain* is defined as a set of categories that is distinguishable from other sets by a specific (major) purpose served by the domain. Once the purpose of a domain is specified, the domain may be a *field* or an *area* or even a *set of domains*.

These definitions make possible organized discussions involving hierarchies or other structural types involving categories.

Categories for Systems and Complexity. What categories might be appropriate for the study of systems? or of complexity? Having begun a study of complexity over 30 years ago, a collection of materials slowly evolved, ultimately amounting to over 700 transparencies organized by presentation topics, with dozens of books and articles.

To organize such a collection as it grew, and retain ease of building on previously constructed materials, it was necessary either to begin with or to invent some categories. Given the logic asserted in the foregoing, it was felt that low-level categories should evolve and, that over time, higher-level categories could be found by combining elements from lower-level categories. In this way, prejudice concerning what categories to use, if not totally vanquished, could perhaps be minimized. Use of this strategy is called *"bottom-up" categorization*.

Table 1 shows the culmination of an initial categorization, listing the initial elemental categories[8].

TABLE 1 INITIAL CATEGORIES OF RESEARCH RESULTS
Numbers appearing represent the number of
contained computer files rounded to the nearest ten

Biographical, emphasizing excerpts from other scholars (BI, 60)

Case study information (CA, 90)

Specifically and directly tied to complexity (CO, 180)

"Clanthink" (CT, 30)

Topics related specifically and directly to education (ED, 80)

Topics related specifically and directly to history (HI, 10)

Files tied directly to Interactive Management (IM, 70)

Files tied to "knowledge) (KR, 30)

Learning Organization (LO, 10)

Laws of complexity (laws-related, LR, 60)

Management (MG, 30)

Mathematics of Modeling (MM, 70)

Philosophy (PH, 30)

Productivity in organizations (PROD, 10)

Science (SC, 40)

How many (total) files were involved with the foregoing categories? Table 2 lists numbers of folders, files in folders, and total megabytes of information, categorized by the name of the application program holding the information.

TABLE 2. QUANTITIES OF MATERIAL IN VARIOUS CATEGORIES

Software Application	Number of Folders	Number of Files	Number of Megabytes
WPWin 8.0 and previous versions	335	3,559	157
Aldus Intellidraw 2.0	10	139	7.5
Ventura Publisher 4.0	52	3,667	22.5
TOTALS	397	7,365	187 Mb

As the work progressed, even after those categories were chosen, it became almost impossible to retrieve anything, due to the increasing volume of materials and the dependency of newly-conceptualized material on material previously chosen. This lowered significantly the efficiency of the research work, and provided a powerful incentive to create categories (finally) that would make easier the task of relating ongoing work to previous results.

Constructing the Basic Fields and Areas. It was decided to approach the finding of categories for organizing the information from three angles. First, it was decided to place over *600 transparencies* in categories. The initial result of this produced about *100 categories*. Then those were placed in categories. The results were *10 inclusion fields*. Finally, these *10 fields* were placed in *4 inclusion areas*.

Testing the Inclusion Domains by Content Analysis. Second, it was decided to construct categories from the contents of a 525-page set of *21 essays on complexity* that were produced over the years[9]. This effort produced *6 fields*.

Finally, the *20 laws of complexity*[10] were placed in fields. This effort produced just 3 main fields, one of which had 3 sub-categories.

These various results are shown in Tables 3, 4, 5, and 6.

TABLE 3. TEN INCLUSION FIELDS (CATEGORIES) PRODUCED FROM OVER SIX HUNDRED TRANSPARENCIES ON COMPLEXITY
(Numbers show how many transparencies were involved in each field.
Some were involved in more than one field)

A. SCIENCES (120)

B. LANGUAGE (100)

C. HUMAN BEING (80)

D. MODELS (60)

E. PROCESSES (50)

F. EDUCATION (50)

G. ORGANIZATIONS (40)

H. REASONING THROUGH RELATIONSHIPS (30)

I. FORMALISMS (20)

J. THOUGHT LEADERS (20)

The set of ten inclusion fields proved to be very serviceable. It was possible to find older work with minimum effort and, as new transparencies were created, it was easy to sort them into one or more of the ten fields.

The number ten is fine for sorting purposes, but it is too large for general exposition. So the four categories ("areas") that were produced from these ten satisfied a second need: namely exposition to discuss how the various components of research on complexity were interrelated. These four areas served that purpose nicely.

TABLE 4. FOUR *AREAS* PRODUCED FROM THE FIELDS IN TABLE 3

Infrastructure of Science

Sciences

Applications of Science

Organizations (The Site of Applications of Science)

Testing With Categories Drawn from The Domain of Science Model. In an earlier work[11], four categories were chosen and displayed in an interrelationsip called the "Domain of Science Model". The categories shown in that circular

model were: Fundamentals, Theory, Methodology, and Applications. These four elements were asserted to lie in a circle, each drawing on its predecessors. There is not a perfect match between the older set and the newer set. In this more recent set of four areas, the area denoted "infrastructure of science" assumed greater prominence than in the older categories. It may be helpful in understanding this to know which of the ten fields found their way into this infrastructure area.

The *area Infrastructure of Science* subsumed five of the ten fields, with the approximate number of transparencies drawn from them shown in parentheses:

A. The Human Being (60)
B. Language (20)
C. Reasoning Through Relationships (10)
D. Thought Leaders (50)
E. Formalisms (10)

The *Sciences* area F was an *area* unto itself. It incorporated about 130 transparencies. These transparencies were comprised of chronologies (showing how sciences evolved), laws (representing principal findings of the sciences), empirical evidence (the accumulated evidentiary support for the laws), and types of sciences (showing divisions along academic lines).

Applications of Science subsumed three of the ten *fields*, these being:

G. Models (30)
H. Processes (40)
I. Education (20)

Finally *Organizations* J (the site of application of the sciences) was an area unto itself. It incorporated about 30 transparencies.

The total number of transparencies contained in these categories is less than the number stated originally in this manuscript. This is because several hundred were eliminated as being essentially of an administrative nature, rather than contributing to the scientific components of the study.

Testing With Categories from 21 Essays on Complexity[12]. The study of categories drawn from the 21 essays on complexity was undertaken as a kind of cross-check on the categories described above. It would, hopefully, uncover any

categories that had been overlooked, or else it would reinforce what was already learned.

TABLE 5. SIX CATEGORIES FOUND FROM 21 ESSAYS ON COMPLEXITY
(The number in parenthesis shows how many essays dealt primarily with which category)

E-1. Organizational Enhancements (10)

E-2. Organizational Flaws (5)

E-3. Science and Organizational Behavior (3)

E-4. Linguistic Constraints (1)

E-5. Views on Complexity (1)

E-6. University Redesign (1)

Comparing these six categories with previously-described findings, the following conclusions were reached:

- E-1 could be viewed as an aggregate of components of G, H, I, and J.
- E-2 could be viewed as an aggregate of components of A, H, and J.
- E-3 could be viewed as an aggregate of F, G, H, and J.
- E-4 correlated very closely with B.
- E-5 could be viewed as an aggregate of components of C, H, and J.
- E-6 is a high-level design intended to apply to E, integrating components of all the other fields[13]

It was concluded that fields A-J inclusive had collectively passed the tests, as had the subsuming areas. It remained to correlate fields A-J with categories arrived at from the published 20 laws of complexity.

Testing With Topics in 20 Laws of Complexity[14]. Table 6 shows categories found by content analysis of 20 laws of complexity.

TABLE 6. CATEGORIES OF 20 LAWS OF COMPLEXITY
(Some laws were based in more than one category)

- Behaviorally-Based (14 laws, 70%)

- Mathematically-Based (6 laws, 30%)

- Media-Based (2 laws, 10%)

The behaviorally-based laws were placed in three sub-categories, as follows:

- **Habitual** (behavior that people display without giving much thought to it, but which could be changed if the habit were changed, 7 laws)

- **Organizational** (behavior that people display when they are operating inside an organization and are subject to its constraints, and which they believe can be changed only at substantial personal risk, 5 laws)

- **Physiological** (behavior that people display as a consequence of their physiology, and which is not easy or even impossible to change, 5 laws)

Some laws are contained in more than one sub-category.

The Behaviorally-Based category drew directly on basic fields A and J, as might well be expected, since A is The Human Being and J is the organization.

The Mathematically-Based category drew directly on basic fields B, C, D, E, G, and H.

The Media-Based category drew on basic fields B and G.

Given these correlations, it was again felt that the ten basic fields had passed the test of being adequate to discuss complexity. This did not mean that the ten were best suited for all purposes or occasions, but that the test categories were representative of what was contained in the ten fields hence, also, in the four areas.

Still one more set of categories was developed. In contrast to the foregoing, all of which were constructed by sorting various products which evolved over a long period of time, the following set of categories to be described was arbitrarily chosen, but was based on almost 20 years of experience in observing what went on

in Interactive Management Workshops (of which approximately 500 had been held by the time this next set of categories was chosen).

Based on all that was learned in developing the categories mentioned so far, and on the experienced just mentioned, it was decided that in order to understand and to resolve complexity a certain pattern of behavior was necessary (though not necessarily sufficient). This pattern was named "The Work Program of Complexity" (WPOC).

The WPOC involves just two overarching categories. They are

- Discovery
- Resolution

These two categories reflect almost all of traditional scientific experience. There is first, discovery, and there is second, application of what was discovered to resolve some situation. In this respect, these categories are hardly new. Yet they reflect a highly-detailed pattern of group activity.

Each of these two overarching categories can be divided into two sub-categories. Discovery is divided into:

- Description
- Diagnosis

These two activities basically describe the situation that is perceived, and having done this in a disciplined way, the diagnosis can be made based on the best available description.

Resolution is divided into sub-categories:

- Design
- Implementation

Once the situation is diagnosed, the challenge is one of designing a response. And that challenge is followed by implementation of the chosen design[15].

All of this activity demands an excellent working infrastructure (distinguished

from the infrastructure of science). This working infrastructure, itself, has several components. Some are informational, some are human, and some are physical.

Still one other set of categories, developed several decades ago, related to relationships. Curiously, the relationships dealt with by most authors seem to have been intuitively conceived and do not even surface as particular topics related to choice. Far and away the bulk of the discussions in the scientific and other literature focus upon the elements being related, rather than the relationships that are used to relate the elements. For completeness, this long-standing[16] set of categories appears in Table 7.

While each category in Table 7 illustrates the concept of "inclusion relationship" mentioned earlier, it can be seen that that type of relationship also appears as a member of the category "Definitive". In other words, when an element is asserted to be a member of a category, this assertion is to be seen as an arbitrary, hence definitive, act. The act of placing the member in the category need not be subject to validation any more than any other definition is so subject. Still, if it does not meet a test of "reasonableness" based on experience, it is likely to be an empty act, possibly "full of sound and fury, signifying nothing".

TABLE 7. SIX CATEGORIES OF RELATIONSHIPS AND EXAMPLES OF EACH

DEFINITIVE	COMPARATIVE	INFLUENCE	TEMPORAL	SPATIAL	MATHEMATICAL
Includes	Is greater than	Causes	Must precede	Lies east of	Is a function of
Is Included in	Is heavier than	Affects	Must follow	Lies west of	Affects the like-
Implies	Is preferred to	Aggravates	Precedes	Lies to the right of	lihood of
Is a member of	Is of higher	Enhances	Precedes or	Lies to the left of	Can be computed
Covers	priority than	Supports	coincides with	Lies above	from
Is a partition of	Is of equal or	Confirms	Requires more	Lies below	Is computable
Is necessary for	higher priority	Weakens	time than	Has a component	from
Is sufficient for	than	Strengthens	Overlaps in	that lies to	Is disjoint with
Is in the same	Is more useful	Is dependent on	time with	the left of	Has a non-zero
category as	than	Modifies	Is disjoint in	Crosses in a	intersection with
Is assigned to	Is more important	Is a partial cause	time with	plane	Equals
Is associated	than	of			Is greater than
with	Is more critical				Is less than
Is reachable	than				Is greater than
from	Requires more				or equal to
Is isomorphic	space than				Is congruent
with					with
					Is a cover of
					Is a partition of
					Is a greatest
					lower bound for

Introduction of Table 7 at this point in this manuscript enables discussion of categories of elements that may be related by categories of relationship other than "definitive".

With an inclusion relationship only, elements may appear in categories, and those categories may appear in other categories, and so on indefinitely. Only the first in a sequence may involve what Leibniz called a "monad". Ever after, everything is a category. Division and aggregation are the tasks of which categories are formed.

Many other instances of relationship involve categories related by other kinds of relationships. For example, categories may be related by priority relationships or by influence relationships. The possibilities are very large. But in virtually every instance there are at least two relationship types involved, one of which is a definitive relationship: namely, inclusion.

Having found these various categories, the question arose as to how best to present the substance of the various arguments involving these categories under the general topic of "complexity". No single answer was found to this question, but the following distinct outcomes, called "program areas" were developed:

- **"The Complexity Lectures"**, one such lecture being given each week over a semester, primarily for faculty and students; with the aim of developing interest and sufficient overview to cue subsequent study of complexity

- **"The Curriculum of Complexity"**, formed as a guide for a type of two-semester college credit course, intended to serve students and faculty in the classroom

- **"Managing the Unmanageable"**, formed as a set of slide presentations to educate managers or would-be managers in a one-week or two-week short course[17]

The choice of categories in these three program areas was conditioned by the purposes assigned to the programs and by the categories found previously. Each of these program areas will be discussed in turn.

The Complexity Lectures. The four main categories chosen for this set of lectures were:

- Philosophy of Complexity
- Science of Complexity
- Applications in Industry and Government
- Implications for Higher Education

Three groups of lectures were developed, each group containing one presentation from one of the four categories, as shown below.

GROUP 1. (Weeks 1-4)

- **September 14**. *Philosophy 1*. Thought Leaders and Their Contributions to Understanding Complexity

- **September 28**. *Science 1*. Twenty Laws of Complexity, Three Categories of the Laws, and Five Indexes of Complexity, with values determined from applications.

- **October 5**. *Applications in Industry and Government 1*. Applications in the U. S. Food and Drug Administration and in state and local government in Mexico (presented initially by Dr. A. N. Christakis[18]).

- **October 12**. *Implications for Higher Education 1*.

GROUP 2 (Weeks 5-8)

- **October 26**. *Philosophy 2*. Seven Milestones in the History of Thought.

- **November 2**. *Science 2*. The Mathematics of Structure: its relevance to knowledge reconstruction in all fields of study

- **November 9**. *Applications in Industry and Government 2*. Applications in Ghana, Liberia, and Cyprus (presented initially by Dr. Benjamin Broome[19]).

- **November 16**. *Implications for Higher Education 2.*

GROUP 3 (Weeks 9-12)

- **November 23**. *Philosophy 3*. The Legacy of Charles Sanders Peirce and the Experience of the Peirce Biographer.

- **November 30**. *Science 3*. The Role of the Normative Sciences in Strategic Planning

- **December 7**. *Applications in Industry and Government 3*. Applications in Ford Motor Company, U. S. Department of Energy, and U. S. Department of Defense.

- **December 14**. *Implications for Higher Education 3*

A Curriculum of Complexity. For the long haul in education, categories were developed for a curriculum of complexity. These categories satisfy the inclusion relationship, meaning as before that they are defined by the elements which are contained in them (including other subcategories, if any); but also by a prerequisite relationship in which, e.g., A is prerequisite to B. However this relationship is incomplete, since some components may be corequisite; i.e., understanding each is essential to understanding the other. Since learning inevitably takes place sequentially, corequisite necessarily involves moving back and forth between topics. Structurally, corequisites are part of a cycle.

The curriculum is described in Figure 1. At this point, the reader can probably connect the categories shown in Figure 1 to those given previously. Figure 1 elaborates on components in the categories.

Because all of the energy that is expended to understand complexity goes for naught if it lies fallow, the final set of categories discussed here was chosen and expanded to apply to organizational management. A set of slide presentations was developed under the rubric "Managing the Unmanageable". The idea behind this title is that whatever is to be discussed is a situation that is unmanageable—it has

defied management. On the other hand, it is possible to transform the complexity that is involved into understanding. The key to doing that is to apply The Work Program of Complexity. That can be accomplished using a system of management titled "Interactive Management" which has been thoroughly described[20].

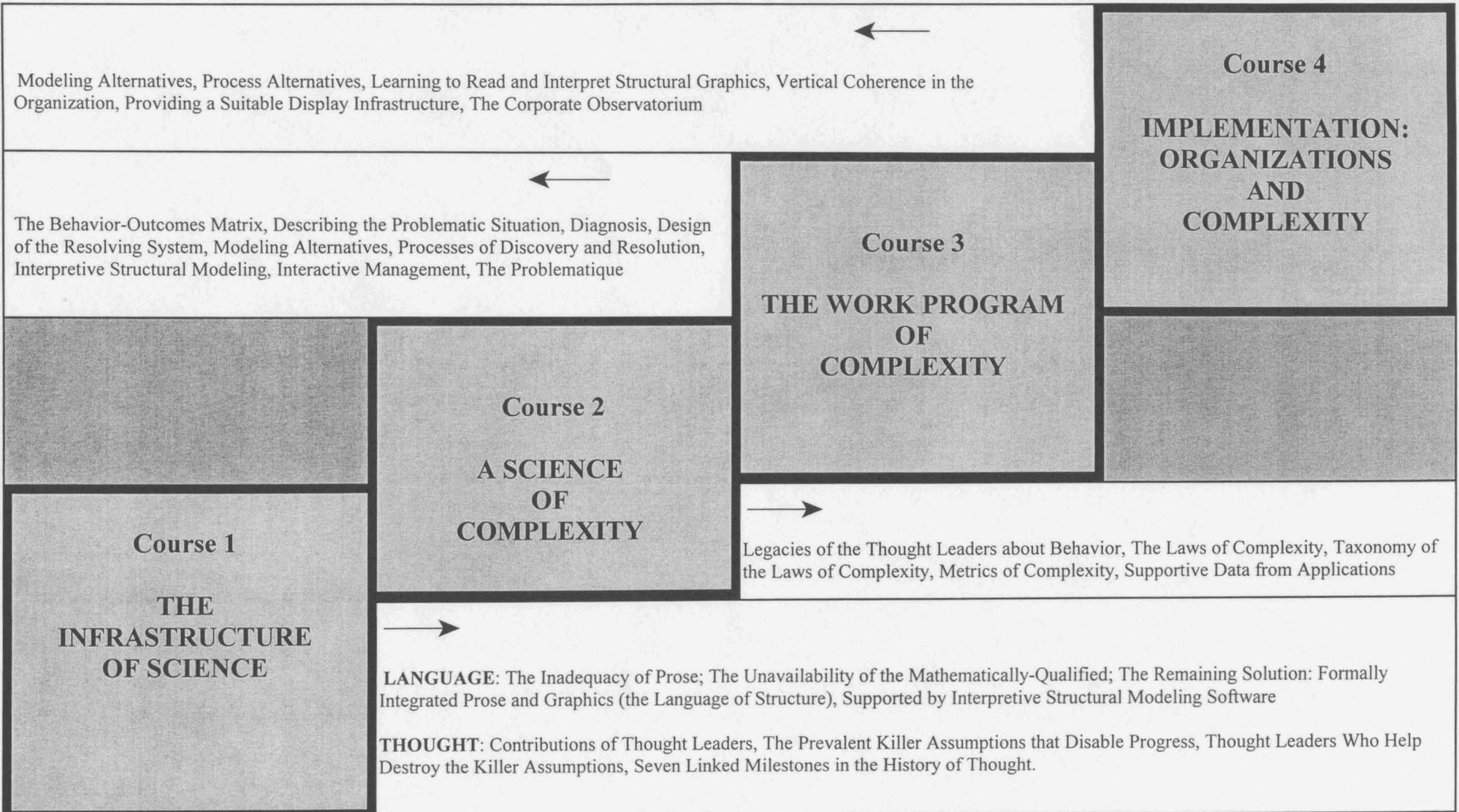Categories used with Interactive Management include the definition of three phases, which are:

- Phase 1: The Planning Phase, leading to an Interactive Management Workshop Plan

- Phase 2: The Interactive Management Workshop

- Phase 3: The Followup.

This set of three phases can be applied to the Description component of Discovery. It can be re-applied to the Design component of Resolution. These are the most common applications of Interactive Management. Followup should always include an interpretation session, to feed back to the participants an interpretation of their work. This is because it has been discovered unequivocally that people believe they can interpret graphics, but they cannot do so without substantially more education in reading graphics[21].

Particularly important is the distinction between linear and nonlinear structures. The terms "linear" and "nonlinear" have long been used in science with reference to physical systems. The terms are, however, structural terms and it is highly unfortunate that these terms have become embedded in the scientific and engineering literature. Linear normally has implied that superposition applies; i.e., the response of a system to multiple inputs is the same as the sum of the responses to the separate inputs. Nonlinear then is defined as the absence of linearity. Better terms should be found to make such distinctions, because the terms are essential to understanding how to portray complexity.

Prose is the prototypical linearly structured communication medium. Trying to describe complexity with prose alone amounts to trying to fit concepts into a medium that is not coherent with the complexity that is involved.

Figure 1. THE CURRICULUM OF COMPLEXITY

Modeling Alternatives, Process Alternatives, Learning to Read and Interpret Structural Graphics, Vertical Coherence in the Organization, Providing a Suitable Display Infrastructure, The Corporate Observatorium

The Behavior-Outcomes Matrix, Describing the Problematic Situation, Diagnosis, Design of the Resolving System, Modeling Alternatives, Processes of Discovery and Resolution, Interpretive Structural Modeling, Interactive Management, The Problematique

Course 4

IMPLEMENTATION: ORGANIZATIONS AND COMPLEXITY

Course 3

THE WORK PROGRAM OF COMPLEXITY

Course 2

A SCIENCE OF COMPLEXITY

Course 1

THE INFRASTRUCTURE OF SCIENCE

Legacies of the Thought Leaders about Behavior, The Laws of Complexity, Taxonomy of the Laws of Complexity, Metrics of Complexity, Supportive Data from Applications

LANGUAGE: The Inadequacy of Prose; The Unavailability of the Mathematically-Qualified; The Remaining Solution: Formally Integrated Prose and Graphics (the Language of Structure), Supported by Interpretive Structural Modeling Software

THOUGHT: Contributions of Thought Leaders, The Prevalent Killer Assumptions that Disable Progress, Thought Leaders Who Help Destroy the Killer Assumptions, Seven Linked Milestones in the History of Thought.

The individual presentations on Managing the Unmanageable, and the number of slides in each are as follows:
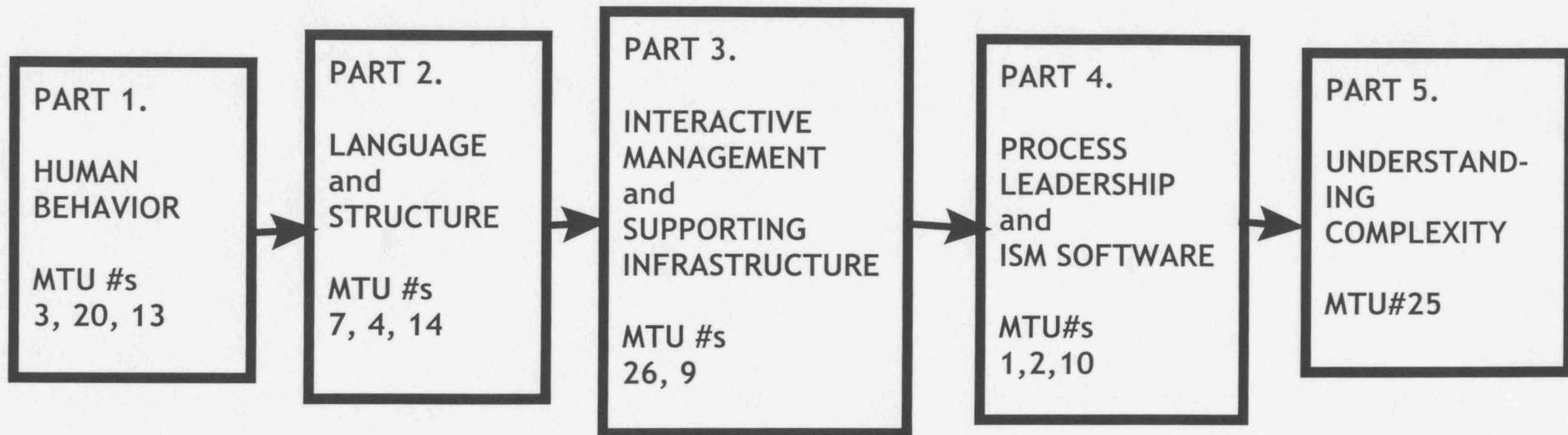
- Process Leadership in Organizations (67 slides)
- Interactive-Management-Process Leaders and Their Work (43 slides)
- Thought Leaders on Behavioral Pathologies (27 slides)
- The Mathematics of Structure (66slides)
- Thought Leaders on Second-OrderThought (Thought About Thought) (45 slides)
- Infrastructure for the Work Program of Complexity (36 slides)
- Why Johnny Can't Design Software(19 slides)
- Managerial Self-Delusion via Killer Assumptions (48 slides)
- Language for Use in ResolvingComplexity (47 slides)
- Key Theorems of Modeling (Friedman, Harary, and Ashby contributions) (11 slides)
- Understanding Complexity, including "Metrics of Complexity" (42slides)
- Interactive Management (22 slides)
- Quality Control in Complexity Modeling (24 slides)

A one-week short course involving most of these presentations was offered to 42 Mexican students at the University of Hull in the summer of 2001, organized as shown in Figure 2.

Three Domains of Complexity. All of the foregoing can be described, in overview, as represented by three domains of complexity, which are:

- **The Basic Relationship Fields (Table 7)**, the purpose being to show categories from which types of relationships, and members of the types can be chosen for purposes of model construction, including especially structural models

- **The Basic Element Fields and Areas (Tables 3 and 4)**, the purpose being to show how empirical work has produced a set of categories whose contents support the development and application of a science of complexity, based in structural and behavioral considerations

- **The Program Domains**, whose purposes are to provide learning materials suitable for particular modes of delivery and particular audiences

Figure 2. University of Hull Course on Complexity Structure, Summer 2001

PART 1. HUMAN BEHAVIOR MTU #s 3, 20, 13	**PART 2.** LANGUAGE and STRUCTURE MTU #s 7, 4, 14	**PART 3.** INTERACTIVE MANAGEMENT and SUPPORTING INFRASTRUCTURE MTU #s 26, 9	**PART 4.** PROCESS LEADERSHIP and ISM SOFTWARE MTU#s 1,2,10	**PART 5.** UNDERSTAND- ING COMPLEXITY MTU#25

The above is a rough outline of what was used for lectures at the University of Hull course for Mexicans, during my week of July 2-6, 2001.
In most cases, I didn't use the last MTU in a sequence. For example, in Part 1, I didn't dwell on MTU #13, and in Part 2 I didn't dwell on MTU #14.
There wasn't enough time. But all of the MTUs listed above were distributed to all the students. In addition, we did an ISM session in Part 4, using the old DOS-based software. Students were told that they may be able to download this software free along with the User Guide, by going to the GMU web site http://www.gmu.edu/departments/t-iasis.

C:\MY FILES\Categories.wpd
September 22, 2001

As with all products of scientific exploration, these domains are subject to amendment and extension. They have been produced over a period of more than 30 years, and their component categories have been tested in many ways. As a result, they should prove to be robust, i.e., capable of being confidently applied and widely used. But a decision on whether such judgments are correct must naturally be left to the reader.

END NOTES:

1. Tredennick, H. (Trans., 1938): **Aristotle: Prior Analytics**, London: Heinemann.

2. The distinction between hierarchies and cycles is widely blurred in numerous disciplines and in much literature. Correcting this oversight requires that more attention be given to structure, as exemplified by Frank Harary and his colleagues in their 1965 book on structural modeling. To understand the distinction thoroughly, one can benefit from cross-comparisons of various branches of mathematics. A reasonably complete exposition, using consistent notation, was presented in middle chapters of the 1976 book: John N. Warfield, **Societal Systems: Planning, Policy, and Complexity**, New York: Wiley Interscience. An outstanding illustration of the distinction in application appears in the 1976 paper by Zamierowski, Hornbach, and Fitz: **"Ecological Components of Climax Agriculture: An Example of Structuring Complex Feedback Systems"**, appearing in the *Proceedings of the International Conference on Cybernetics and Society*, New York, Institute of Electrical and Electronics Engineers, pp 667-673.

3. The process known as "Interpretive Structural Modeling", published in the Warfield reference cited in End Note 2, instruments Aristotle's concept of syllogism in deductive logic, using Frank Harary's Theorem of Assured Model Consistency. Use of this process enables groups to construct very tight logic structures consisting of hundreds of linked syllogisms. This process was used by the Fitz group to get the results relating to climax agriculture cited in End Note 2.

4. The U. S. Congress passed a law in 1994 based on extensive work by Dr. Henry C. Alberts using Interpretive Structural Modeling extensively with over 300 program managers from the United States Department of Defense. This law is known as Public Law 103-355, **"Federal Acquisition Streamlining Act of 1994"**.

5. A mature perspective on discoveries related to human reasoning can be gained by studying works of the American philosopher, Charles Sanders Peirce, along with the outstanding work of I. M. Bochenski titled **"A History of Formal Logic"**. An understanding of mathematics is not essential to read such materials but, as would be expected, it would help.

6. Ten years as head of a department at the *Collège de France,* dedicated to the study of the history of systems of thought, provided Michel Foucault with unique insights, many of which are relevant to understanding complexity. The extensive body of his work has been partially and creatively captured by Paul Rabinow in his book titled **The Foucault Reader** (1984, New York,

Pantheon). Interviews with Foucault taking place shortly before his death, enabled these insights to be clarified and made more accessible. My long-time colleague, Roxana Cárdenas introduced me to this book. She is Professor of Systems Engineering at the Instituto Tecnologico y de Estudios Superiores de Monterrey (ITESM), in Monterrey, Mexico, with branch campuses throughout Mexico..

7. These distinctions are discussed in Warfield (1976), identified in End Note 2.

8. The purist may assert that relationships are also elements. Relationships can be treated like elements for the simple reason that relationships can be related to one another. Sometimes it is important to let practical reason dictate how terms are used. In numerous applications and discussions, no one has ever raised the issue mentioned here, and interested parties have all been able to cope with the distinction between elements and relationships, as applied.

For those wishing more technical distinction, in all recent memory I have used the term "relation" to refer to a formal mathematical construction, specifically to a set of paired elements (paired in the order in which a relation holds); and the term "relationship" to refer to the "real-world" concept that is associated with a mathematical relation. Such distinctions are critical in applying mathematical concepts to human situations. From a linguistic standpoint, elements are usually nouns, and relationships are usually verb forms, e.g., "significantly aggravates".

9. The titles of the 21 essays are as follows:

"Technomyopia Threatens Our National Security", "Some Magnificent Academic Trusels and Their Social Conditions", "The Learning Organization: Its Relevance to Policymaking", "Widely-Ignored Subtleties that are Critical to Decision-Making", "Procrustes is Alive and Well and Teaching Composition in the English Department", "Accelerating Productivity of Industrial Organizations", "Groupthink, Clanthink, Spreadthink, and Linkthink: Decision-Making on Complex Issues", "Spreadthink: Explaining Ineffective Groups", "Demands of Complexity on Systems Science", "Structural Thinking: Organizing Complexity Through Disciplined Activity", "Five Schools of Thought About Complexity", "The Corporate Observatorium: Sustaining Management Communication and Continuity in an Age of Complexity", "The Wandwaver Solution: Creating the Great University", "Mentomology: The Identification and Classification of Mindbugs", "A Platform for Sociotechnical System Design", "A Role for Formalisms in Integrative Studies", "Twenty Laws of Complexity: Studies in the Abuse of Reason", "The Problematique: Evolution of an Idea", "Readings for Bureaucrats", "Seven Ways to Portray Complexity", and "A New Index of Complexity: The Aristotle Index".

10. J. N. Warfield (1999), **"Twenty Laws of Complexity: Science Applicable in Organizations"**, *Systems Research* 16(1), 3-40. These laws were accumulated slowly, starting about two decades earlier. The paper describes their origins and provides references, where available.

11. J. N. Warfield (1990, 1994), **A Science of Generic Design: Managing Complexity Through System Design**, 1ˢᵗ Edition Seaside, CA: Intersystems, 2ⁿᵈ Edition Ames, IA: Iowa State University Press.

12. See End Note 9, where the 21 essays are identified by title.

13. J. N. Warfield (unpublished, but available on the web at http://www.gmu.edu/departments/t-iasis) **The Wandwaver Solution: Creating the Great University**, first produced as a report from the one-time Institute for Advanced Study in the Integrative Sciences, 1997.

14. See End Note 10 for a citation.

15. In 1980, a set of categories presented by the late H. A. Simon was chosen for initial visualization of what kind of processes might be required. This categorization incorporated, in time sequence, intelligence, design, choice, and review. These four categories have been replaced with those in the Work Program of Complexity. Comparing the new with the old, it is reasonable to say that intelligence has been replaced with discovery and diagnosis. This replacement has taken place because discovery is best carried out in groups, while diagnosis is best done initially by an individual who presents the results to the group for their learning and possible amendment. Design remains undisturbed as a category, but choice is folded into the design activity, where the means of arriving at the choice are spelled out in detail. Review has been replaced with implementation.

16. These categories were published in the book on generic design identified in End Note 11.

17. Hastily-done videotapes on many of these topics are available in the libraries of George Mason University, Fairfax, VA, in the "Warfield Special Collection"; and of George Washington University, Washington, D. C.

18. Dr. A. N. Christakis is President of CWA, Limited, practicing Interactive Management from a headquarters in Paoli, Pennsylvania.

19. Dr. Benjamin Broome is Professor in the Hugh Downs School of Communication, Arizona State University, Tempe.

20. Interactive Management is thoroughly discussed in J. N. Warfield and A. R. Cárdenas (1994), **A Handbook of Interactive Management**, Ames, IA: The Iowa State University Press.

21. The inability of people to read structural graphics was not recognized initially in the work. Several years of experience finally led to the conclusion that interpretation by a person who is heavily experienced in reading such graphics is essential. Two dissertations shed light on this subject. The first one was a Ph. D. dissertation: Janet Fertig (1980), **"An Inquiry into Effective Design of Graphicolingual Displays for Systems Engineering"**, University of Virginia. This research focused on the use of text boxes, which is very common in engineering. A key finding was that about eight words are required to convey meaning with minimal ambiguity. A single

word, which is typical of many engineering graphics, conveys far too little information. Going well beyond eight tends to introduce too many cues. The second Ph. D. dissertation was: George H. (Tony) Perino (1999), "**Complexity: A Cognitive Barrier to Defense Systems Acquisition**", George Mason University. This dissertation unequivocally demonstrated the necessity (for the present) of interpretation by an experienced specialist, as well as the high desirability of introducing graphicolingual communication into higher education, at least for people who may become involved in understanding or designing large systems. Some of the results of this research were frightening, given the huge sums that are invested in large-scale systems and the lack of understanding of the many relationshps involved in their design and operation.