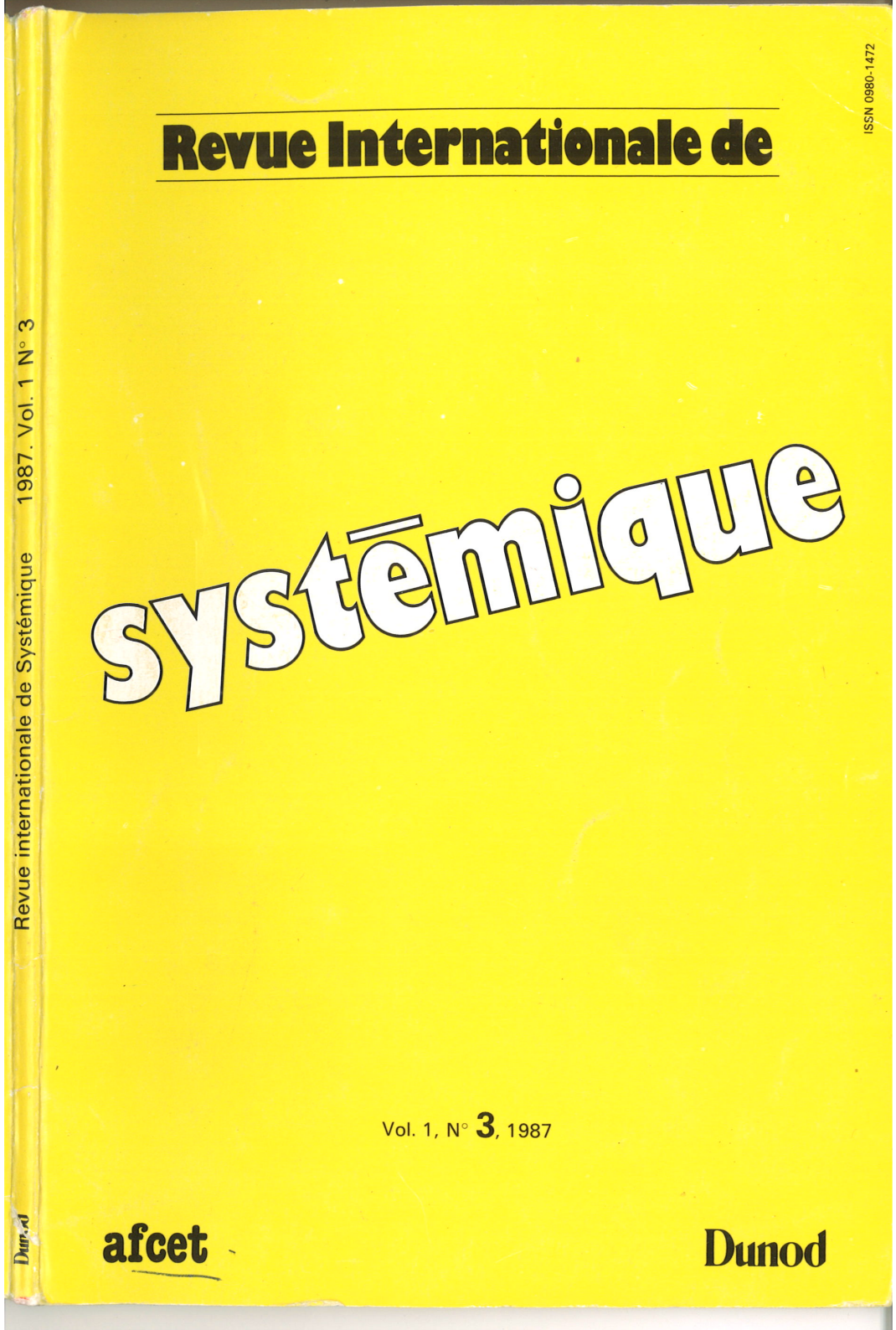

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Levels of logic and of abstraction and the metasystem paradigm

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nous proposent aujourd'hui le *Discours pour les Nouvelles Sciences* que nous pouvons et devons revendiquer pour assurer notre droit à produire et à valider des énoncés enseignables. A condition bien sûr que nous ayions sans cesse l'exigence intérieure de cette prométhéenne ambition : «*Et avant que le chercheur ne se livre à cette lutte avec l'ange, un peu d'ascèse ne lui serait sans doute pas inutile*» [52].

N'y a-t-il pas urgence ?

52. Conclusion de R. Thom à son article «La Science malgré tout» dans l'«Organum» de l'Encyclopedia Universalis (repris dans le volume «Enjeux» de la Nouvelle Edition).

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LEVELS OF LOGIC AND OF ABSTRACTION AND THE METASYSTEM PARADIGM

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Abstract
The metasystem paradigm generates an effective methodology to induce the process of critical thinking. The sequential processes of reasoning used to produce understanding can best be conceived as taking place at differentiated levels of logic and of abstraction, in a hierarchy of reasoning processes encompassing description, explanation, prediction, understanding and, finally, innovation and knowledge creation. The importance and the role of the hierarchies of logic and of abstraction in Critical Thinking are described and emphasized.

Résumé
Le paradigme des métasystèmes génère une méthodologie qui se prête à décrire le processus de la réflexion critique. Le déroulement de la pensée peut se comprendre comme une série d'opérations qui prennent lieu à différents niveaux de logique et d'abstraction. On peut donc concevoir une hiérarchie de procédés de réflexion qui produisent, à tour de rôle, la description, l'explication, la compréhension, et finalement, l'innovation et la création de nouvelles connaissances. L'importance et le rôle des hiérarchies de logique et d'abstraction dans le développement de la réflexion critique sont décris et discutés.

The Metasystem Paradigm (van Gigch, 1987a & 1987b) is derived from the Systems Paradigm (van Gigch, 1978). It postulates all the biological-behavioral assumptions of the latter and, in addition, views the organization as a recursive hierarchy of control systems. Each

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system is made up of a Controller (CR) which acts upon a Controlled System (CS). In turn, a Metacontroller (MCR) oversees the controller. Each control system has an environment (E) which defines the influences, upon the control system, which exist outside the system (C). The controller (CR) acts at the *object level*, the controlled system (CS) at the *intervention level*, and the metacontroller (MCR) at the *metalevel*. Through recursion, the hierarchy can be repeated so that a succession of metacontrollers MCR', MCR", MCR"'... etc., can be added upon one another. To date, the application of this paradigm to organizational problems has yielded a wealth of information about the *content, logic, language,* and *properties* of the various inquiring systems in the hierarchy. It has also helped to increase our understanding of *the differences* of these properties across system levels. Thus, the metasystem paradigm can be characterized as follows :

1. It is a process of study or of inquiry.

2. It is concerned with epistemological inquiry, i.e., with the study of reasoning and knowledge acquisition processes and how they work.

3. Given the particular meaning of the word «hierarchy» (which connotes «an upward movement» «to the origin»)., the metasystem paradigm places particular emphasis on the role and importance of the metalevel and of the metasystem. It emphasizes the inquiry of object level problems from a metasystemic point of view. It focuses on the inquiry of object level problems from a metasystemic point of view. A metasystemic inquiry, always centers on the design and role of the knowledge acquisition processes of an object level system which, by definition, are always located at the metalevel or in the metasystem.

The metasystem paradigm gives rise to a Science of Hierarchies or Hierarchical Systems which is concerned with metasystemic validation of lower level system truths. As will be explained in more detail below, the metasystem paradigm also provides the underpinning of the Science of METAMODELING because is is concerned with the epistemological inquiry of MODELING. Thus, the conventional isomorphisms of System Theory are replaced by explicit heteromorphisms in order to enrich our understanding of the systems domains. The metasystem paradigm forces us to consider the relationships among systems levels and to always take into account metaperspectives. For the present paper, we have chosen to apply the metasystem paradigm to the domain of Critical Thinking.

Critical Thinking

Critical Thinking is only one of the complex thinking processes which can be considered in human cognition. According to Presseinsen (1985), the other three processes are : Problem Solving, Decision Making, and Creative Thinking. In the present paper, our attention will be devoted to Critical Thinking, which has been defined as the determination of whether to accept, reject or suspend judgment about a claim (Moore and Parker, 1986). Mason and Mitroff (1981) and Mitroff (1983) adopted Toulmin's (1958) notation according to which the structure of an argument consists of : The claim of the argument («It is asserted that...») and the premises which justify the claim. Premises are supported by a) evidence or data about the state of the world («Given that...») ; b) a warrant which justifies going from evidence to claim («Because...») ; and c) the backing which legitimizes the assumption inherent in the warrant («Since ... then...»). Mason (1969) and Mason and Mitroff (1981) popularized a form of critical thinking which consists of a dialectic process whereby claim and premises are challenged by counterclaim and counterpremises in order to induce a synthesis or conclusion. According to the metasystem paradigm (van Gigch, 1987a & 1987b), this synthesis takes place through the resolution of conflicts such that «diametrically opposed polarities (which exist at the object level) are absorbed, dissolved, and reconceptualized by invoking, at the metalevel, a consensual position which represents the synthesis or the conclusion of the initial argument». Of paramount importance to critical thinking, is the elucidation of conflicts through a dialectic process whereby the concluding argument or synthesis takdes place at a higher level of logic and of abstraction, two concepts which will be clarified below.

Levels of Logic in Knowledge Acquisition

As explained in more detail in van Gigch (1987b), the process of knowledge acquisition proceeds through several levels of logic, namely : 1) description, 2) explanation, 3) prediction, and 4) understanding. Beyond understanding, we can also visualize 5) innovation and knowledge creation.

Description

To describe : From the Latin, «scribere», i.e., to retrace the characters, and «describere», i.e., to write or copy after the model of nature or after the perception of reality.

Explanation

To explain : From the Latin, «plectere», i.e., to interrelate or connect to previous knowledge, and «explicare», i.e., to clarify.

Prediction

To predict : From the Latin «praedicere», i.e., anticipate or state before it occurs.

Understanding

To understand : From the Latin «apprehendere», i.e., to grasp by the mind, and from Old English, to grasp or seize the meaning.

Innovation

To invent to discover : From the Latin «evenire» and «invenire», i.e., to produce, to invent, to discover. The source and formation of words were obtained from Picoche (1983) and Hoad (1986).

As the mind acquires knowledge, it progresses from the lowest level of logic, where a descriptive model is elaborated, to the highest level where an epistemological model (or paradigm) is elaborated. In between, we use predictive models such as hypotheses and theories, which are suppositions from which further investigation can evolve.

The levels of logic through which knowledge progresses to become accepted Truth can also be identified with increasing levels of abstraction.

Levels of Abstraction in Knowledge

Abstraction Definitions

From Latin : TRAHERE, ABSTRAHERE, ABSTRACTION «To pull», «To separate», «To draw from».

Definition 1. To ABSTRACT : TO ISOLATE OR SEPARATE CERTAIN CHARACTERISTICS FROM ALL OTHERS. In this meaning, to abstract is an action of the mind by which a particular characteristic, property or element is given special attention (isolated concetually or separated) from all others. In abstraction, one isolates conceptually what may not, in fact, be separable (Lalande, 1976). In Aristotelian philosophy, abstraction is a form of inquiry by which the mind separates «form» from «matter» in search of the «universal» (see below) (Reese, 1980).

Definition 2. To ABSTRACT : TO FIND COMMONALITIES, Locke is attributed the following definition : «Abstraction takes place by drawing out what is common to a group of individual things, on the basis of a comparison of their similarities and differences» (Reese, 1980).

Definition 3. To ABSTRACT : TO FIND THE GENERAL AND THE UNIVERSAL. The process of generalization is related to abstraction. When certain characteristics can be observed repeatedly and separated (i.e., abstracted) from the particular cases in which they are embedded, they constitute a general idea which then may also lead to universal (Baldwin, 1940).

Definition 4. ABSTRACTION : AS THE ANTITHESIS OF ANALYSIS. «Abstraction is to be distinguished from analysis» (Baldwin, 1940) with which it differs completely in mode of inquiry and in objectives.

Abstraction in the Discursive Domain

Langer (1967) distinguishes two kinds of abstraction depending whether abstraction is concerned with «discursive thought» or with artistic expression. She calls the former «generalizing abstraction», and the latter «presentational abstraction». This section will deal with «generalizing abstraction» which is the predominant form used in the «discursive domain», i.e., that which is expressed verbally or in writing. Abstraction in the artistic domain is considered elsewhere (van Gigch, 1986b). Again we resort to the metasystem parâdigm with its hierarchical framework as a fruitful tool to conceptualize that abstraction can be carried out at different levels of inquiry. These levels constitute a hierarchy of abstraction levels, in the same way that we posited the existence of a hierarchy of logic levels through which knowledge acquisition takes place. The introduction of the metasystem concept allows us to use the idea that abstraction is a stage-by-stage or level-by-level process, whereby the level of abstraction at each stage or level is raised.

Raising the level of abstraction accomplishes the following : 1) In accordance with Definition # 1 and # 2 above, raising the level of abstraction reduces lower level statements to their common denominator. To «generalize» is to consider lower level objects or statements, and extract their common features from a metalevel perspective. As stated earlier, to separate «form» from «matter» in a substance, is to find its «essence» : In this case, «form» and «matter» are object-level abstractions, whereas «essence» is a metalevel abstraction. 2) In accor-

dance with Definition # 3 above, raising the level of abstraction, raises the level of generality and attempts to reach and apprehend the universal. 3) Raising the level of abstraction of statements or propositions gives place to a logical order, whereby they can be labelled as frist, second, third, etc. – order propositions as suggested by Russell and Whitehead's (1925) Theory of Types. At each level, statements or propositions are said to constitute a CLASS. A CLASS of higher abstraction level, always comprises or encompasses all CLASSES of lower abstraction levels. This ordering and catageorization precludes the advent of paradoxes and ensures the comprehensive and exhaustive listing of decision-making alternatives. 4) Raising the level of abstraction can be used to remove conflicts (in language and in propositions) which exist at lower levels. See van Gigch (1987b).

Logic and Abstraction in Critical Thinking

Logic and abstraction not only play an important role in the process of knowledge acquisition, but they participate in the validation of arguments and in the guarantee of truth. As we described earlier, when we referred to the knowledge acquisition process, raw evidence about the state of the world is processed through several levels of logic. This process validates the internal and external consistency of knowledge statements. Internal consistency ensures that the rules of formal logic are respected and that claims are derived logically from the premises. External consistency ensures the compatibility of internally developed statements with external knowledge about the state of the world.

Processing a claim through the hierarchy of abstraction levels provides ever increasing guarantee of truth. We postulate that lower levels truths are less valid than higher level truths. Truth, in the sense referred to here, should not be confused with the concept of internal or external validity to which we alluded above. Validity does not take into account the value of meaning. Truth as defined here refers to the meaning of a claim in the context of its knowledge domain. For a claim to be true it must be coherent with the accepted paradigm prevailing in the domain in question. Higher level truths (i.e., truths of higher abstraction) carry more weight because they are more encompassing : as the level of abstraction is raised, a claim becomes more general and more universal (recall here the definitions of abstraction given earlier, e.g., Definition # 3). However, one must be very careful not to confuse logic and abstraction with authority. There is no intent to declare that claims of higher logic and of higher abstraction demand higher authority. Authority is an organizational concept which follows a separate hierarchy imperative. Taking into account the above, Critical

Thinking can be redefined as : «*A dialectic process through hierarchies of logic and of abstraction by which the validity and the truth of statements and claims are established and confirmed*».

The Importance of Metaknowledge in Critical Thinking

The dialectic process by which knowledge is processed through the two hierarchies of logic and of abstraction to improve the validity and the meaning of truth produces metaknowledge, the role and importance of which will be explained more fully. We agree with Pitrat (1986) that we must possess metaknowledge (i.e. knowledge about knowledge) in order to be able to evaluate knowledge. Every time that we take object-level knowledge through the dialectic process of validating logic or raising abstraction, we produce metaknowledge, Pitrat (1986) postulates the existence of knowledge and metaknowledge, but rules out the existence of meta-metaknowledge. We disagree with Pitrat, but argue that our disagreement is probably only a matter of definition. The recursivity of the dialectic process ensures that there is always a metalevel to which we can resort to prove the logical and truth validity of statements. The recursive property is only diminished by practical considerations, such as time and cost, and by theoretical limits, as stated in Gödel's Theorem, a subject that will be avoided here.

It is important to realize that the processes of logic and of truth validation, the existence of which we argue in this paper, are at the very basis of knowledge creation. Proceeding from descriptive model to epistemological model and going through explanatory and predictive models increases our *understanding* and enlarges our pool of knowledge. In the end, as knowledge proceeds to climb through the hierarchy of inquiring systems, its level of meaning is increased until it agrees with the established paradigm – the embodiment or essence of all we know in a particular discipline.

Metamodeling : Applying the Metasystem Paradigm to the Process of Modeling

The metasystem paradigm can be used to critically assess a process of inquiry such as Modeling. It illustrates how to overcome the shortcomings of Modeling by elevating the levels of logic and of abstraction of the universe of discourse.

Modeling is known as a knowledge acquisition process which is used to represent perceived reality prior to study. It is interesting to note that the process of modeling has undergone considerable change over time. In van Gigch (1987b), we chronicle that, originally, the only requirement of modeling was *resemblance* between the original and

the model. Today, we seek knowledge *before* representation, and pretend that the essence of modeling is *significance*, instead of mere similitude.

The discipline of Operations Research (O.R.) has made Modeling its hallmark. Of late, O.R. is suffering a decline which could lead to its eventual demise. This decline can be traced to a neglect of its epistemological foundations – a problem which can be avoided by resorting to Metamodeling (van Gigch, 1987c).

Metamodeling is the process of inquiry residing at the metalevel IS (Inquiring System) and which is concerned with the epistemology of lower level systems. In other words, Metamodeling is concerned with the study of the reasoning and knowledge acquisition processes of Modeling. Metamodeling – a metasystemic inquiry into the foundations and applications of Modeling – reveals shortcomings to be avoided :

1. Mere representation without an evaluative component emanating from higher levels of logic, ensures that O.R. models are sterile and lack *significance* : they constitute logical-mathematical manipulations which do not yield solutions applying to realworld clients and recipients. To be meaningful, models must include evaluative rationality which is conceptualized at the metalevel.

2. Usually, the knowledge acquisition process of Modeling is embedded in the Scientific Inquiring System of a discipline. However, Modeling needs to know the world views of the model's recipients. Knowledge of world views is an epistemological concern which stems from the Epistemological Inquiring System of a discipline. We recall that a discipline can be regarded as a hierarchy of three inquiring systems (Practice IS, Science IS an Epistemology IS) which differ in logic, abstraction and language, depending on the problem which is under study (van Gigch, 1987c).

3. We already explained earlier in this paper that UNDERSTANDING and increase of MEANING is the result of the formulation of models of ever higher levels of abstraction and logic, where explanation plays the role of metamodel to the descriptive model ; in turn, theory and prescription is a metamodel to the explanatory model and, finally, the paradigm represents the highest metamodel, because it provides direction and epistemological foundation to all other models.

4. We have argued elsewhere (Hatchuel, Agrell & van Gigch 1987, and van Gigch, 1985, 1986a) that the test of originality and of innovation is to be found at the interface of *theory* and *paradigm* where higher levels of knowledge (metacreation) are conceived or destroyed.

The logic and truth value of critical thinking hinges on the formalization of the processes by which knowledge is validated. A discovery or an innovation only rates as such, once the test of coherence with

previously existing knowledge has been accepted, and that the rules and metarules by which knowledge is validated in the domain in question have been met. Unfortunately, to date, too much emphasis has been placed in the lower level epistemological processes by which knowledge is evaluated. Too little regard has been placed on higher level processes such as metamodeling and the formulation of metarules which must lie at the foundation of a framework by which the logic and truth validity of claims and arguments can be tested.

The problems of disapperaing knowledge can also be discussed in the context of the same framework (de Zeeuw, 1985).

5. The ultimate test of validity of knowledge and a guarantee of truth resides in the continuous confrontation of models against metamodels and of «ordinary science» against «revolutionary» science, in the sense given to these words by Kuhn (1970).

Conclusion

This paper argues for the importance of metasystemic processes by which the logic and truth of claims in critical thinking can be established. The basic dialectic scheme of pitting claim with counter claim and premises with counter – premises at the single level of claim and argument was enlarged to encompass a recursive process repeated at several levels of dual hiearchies of logic and of abstraction in order to reach the highest levels of coherence and of truth.

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