Formal Modelling to Understand Life Systems: Inquiry into the Computation of Life

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Abstract
Information and communication technology (ICT) increasingly controls life and social life. It rests on programmed software, creating formal models of life systems. Resting on which constitutional/evolutional qualities can life systems formally be described? Models are simplifications of realty constrained by purpose. What may they mean for life systems controlled concerning their further development? If but mosaically the paper highlights base formal modelling constituting life systems proposing a transdisciplinary approach. Movement and rhythm ground learning and information transfer. Representation and memory of models of the past and the future originate anticipation. Modelling creates a language of signs, supporting pragmatic heuristics. Modelling copes with complexity generating simplicity in behaviour and handling.
Key words: Logic, evolution, relational models, constructive learning, geometrisation

1. Introduction Prologue: Dialoguing With the Roots of Our World

In a nutshell: Rules in logics ground life systems. Inner/outer environmental contexts shape actual manifestations. Complex adaptive systems (CAS), life systems are surveyed from differing epistemologies. The overarching view understands them as *signs* carrying *orientation, meaning, intent*. Reflecting *relations* they form *relational configurations as networks. These are described by formal models e.g. used for computation. D*ynamic *spaces* are *innate* in formal structures as in the geometry. Intrinsic directionality and meaning occur in formal relations as *lines, circles, arrows, webs.* They guide the emergence of life in *time*. Acting as *developmental drivers/constraints,* implied *cause-effect* relations induce *helical* processes. Following formal principles e*mergence* creates and fills option/action space by *con-figuration.* Complexity and semiosis dynamics ensue *value* and *intent*. Interaction spawns language, culture and mental constructs. .

Complex life constituents as *anticipation* or *learning* can be traced back to the *logic of base conceptual nets* and the *elements contained* therein. In evolution life phenomena gradually developed from primeval base relations. Such pre-models are by nature abstract and ambiguous. For validation they need be *tested against their congruence with reality* as observed in *evolution*. They may be seen and checked e.g. as *heuristic* patterns, exploiting the *potentials* immanent. The critical inquiry reveals the principles governing evolvement, e.g. constructive processes a *self-organisation.*

The procedure originates by most simple modelling using basic logical tools. It likens *thought experiments* to depict as to observe and understand 'real' phenomena.

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Metaphorically: it likens the primeval interplay between the scientists logical pencil and the white space of the sheet (that is, today, ppt on the monitor) to fill in. The formal attempt offers means for a *(meta-)learning heuristic process of systematic research.* The formality of the process helps to unbiased model not *yet* constrained by models specific to culture. Field research in a Non-Western civilisation provides an example. The researcher has to wipe clean his (Western) methodical arsenal down to a blank slate save for the most basic formal notions. He needs begin with basic relations as to build unbiased models, methods and instruments of inquiry and interpretation indigenous to the research object.

Recurring to Aristotle: any unit exists but in its relation with other units, its qualities ascribed by 'relating to' and 'co-acting with'. A second purpose determined step gains meaning, purpose and intent to be observed and reacted upon. A model acts as a *sign* (Hoffmeyer 2008*)*. The argument following presupposes the interplay between signs modelling crucial in scientific reasoning. It leaves open the relations between logic, mathematics and physics, It will restrict to base scientific concepts grounding in basic logical and physical relations. Its focus will remain on *visual signs* and their *physical base and expression,,* that is on *movement.*

A broad topic needs demarcation. The conceptual investigation as follows has been born from teaching and from the need not only to simplify *top down*, but to find the base relations/models constituting reality *bottom up*. To be laid open are the simple frames that establish the difference making the difference. To be found are *the elemental substructures* revealing the *meaningful relational networks* which make the mere connections a (life) system. They serve as a 'point to stand upon'. In particular when exploring new ideas a hold must be secured in base relations for both levering and guidance. No more, but also no less than a background, base relations will guide to order existing connections and detect new relevant ones. In proceeding – induction, deduction and abduction – so far hidden relations may be revealed. They may cause an aha-effect leading to fresh views on known phenomena. In this respect the mode proves useful in systems thinking attempting to ground on basic concepts. Amazingly many concepts are potential objects for such critical re-thinking..

The argumentation as follows will mainly take place in the realms of the *humanities*. It attempts to disclose simple forms of *'relational thinking'* at the base of scientific hypothesizing and subsequent modelling in the social area. It can do so but mosaically. Even thus restricted a 'back to basics' proves a reminder to re-think critically the logics of scientific discovery as to their grounding in formal models. Formal models can be used to understand matter and life-matter up to the neo-cortex of scientists and the texture of societies.

Models evolve from the formal gaining material *embodiment* and semiotic *meaning,* qualities leading to higher consciousness and the human mind. Homo faber will be the bridge-builder behind, the *craftsman*, the designer of his own world (Sennett2008) . The best known example of an ubiquitous, the *Golden Cut, is* found virtually everywhere in nature, science, technology and art.

Humans are life systems internally and socially communicating by languages. *Social communication* co-created a dynamic 'inner' mental control structure to mediate

between the inner individual and outer *social environment*. The use of abbreviating *symbols* to carry meaning generated *symbolic languaging*, in tendency comprehending all sensory inputs. It has been shown that *icons, runes and letters* are built from and reflect basic formal structures expressing meaning assigned. *Science* in particular aligned to analysis, employs *visual symbols*; that is from texts to graphs to visual monitoring of electronic carriers. Historically, following the supremacy of viewing and (less of hearing) in the human species, the spoken language developed into scripture, into printing and with visual electronics highly sophisticated visualizing. Its lead into yet insufficiently known realms originated by the information and communication technology, ICT favouring figures and symbols on the monitors.

"Mathematics is not everything, but nothing is anything without mathematics". Not being a mathematician beyond college level the author can but point to the accelerating progress into ever new 'mathematics' (there is, as Bourbaki has shown, no unified mathematic). Aligning to chemical formal structures a mathematics of life is proposed (Chandler 2009). Basing on the principle of the Klein-Bottle an overarching concept aims to bridge the Cartesian and other cuts in modelling connecting Newtonian logic up to a mathematic of mental concepts (Rapaport 2009).

2. Constructive Modelling towards a Transdisciplinary Formal Base

However sophisticated technical means may show, and how high the level of the abstraction/complexity in scientific argumentation may be, the fundamental *space/time related* structures remain the (lately intensely discussed) base. Reflecting principal relations differentiated and branched in evolution, they shape physical matter as well as physiology (e.g. that of the brain) as thought processes and mental constructs. They constitute the fundamental structures of *perception* and *expression*, of language and of action. *Formal relations carrying meaning expressed in signs* govern the communication, co-action and co-evolution of any life system. Signs constitute any language and communication. Chicks will flee the shadow of a hawk; soldiers follow the banner, and Oxfordians will know each other by accent. By the same token the languages and media of the scientific discourse display distinct features. Scientific argot is but an example for an abundance of highly complex professional languages. They originated following the in se evolving principles of evolution, complexity, semiosis dynamics. With specifications limited to a discipline they become mutually incompatible. Babylon is everywhere; incompatibility proves an incessant rigmarole endangering communication and co-operation. Most dangerous, it affects learning. To regain compatibility languages have to be booted on a shared base of formal models – implying complexity and semiosis.

Compatibility in base structures of languages is evidences by the basic *relational logics* as manifested in complexity dynamics and, for the inevitable emergence of life, in semio-dynamics. Needed is a shared set of models representing the formal ground for all models and the languages arising. An example is given by the concept of *embodiment* connecting so different disciplines as psychology, biology and robotics. Actually they co-operate in the design of sophisticated *robots* intended to simulate

embodied human action as e.g. in services. Recurring to basics: research in these disciplines found unanimously analogies linking *matter and mind with embodiment, movement and control.*

A proposal for a *set of Formal Transdisciplinary Models* is proposed in figure 1. Beginning with relations in the still undifferentiated potentiality field formal base models are ordered following levels of evolvement. It is understood that the figure represents but a rough overview, not showing the intricate interrelations and interpenetrations. Closely connected, figure *2.* suggests a related *Formal Model of Anticipation.* Anticipation will be dealt with I detail in paragraph 3. below.

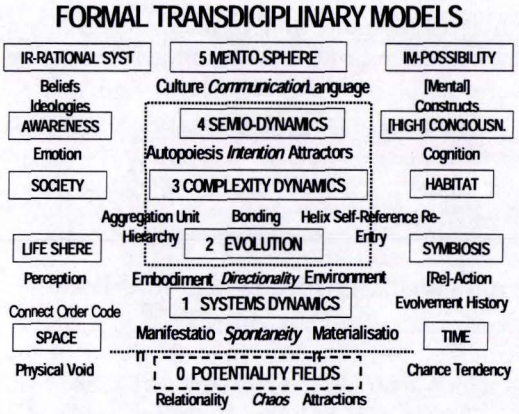


Fig.1 Formal Transdisciplinary Models

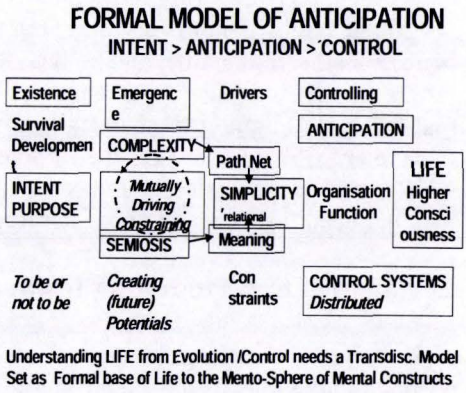


Fig 2 Formal Model of Anticipation

Life evolvement centrally implies purposive construction. Constructive thinking appears a complex process intricately interrelating the physical, the physiological and the mental level. It involves the dynamic *process* as the *institutional* aspect concerning *embodiments* in the nervous system or in bones, tendons, sinews, muscles, the physiological formation of the brain. Consciousness evolved with formal substrates (Edelman 1992). Even *abstract thinking is correlated to movement* and (fine) *movement control in the triad eye, hand and brain.* Conferring with a topic the scientist activates together with his brain and with his nervous network also his kinetic system. Muscles are energized, physical-physiologic structures couple with physical/physiological and informational feed back and control. Feed back responds by direct control information. That happens at any grade of granulation from muscle fibres to brain processes to the awareness the entire personality. Figures of thought may be seen analogous to sequencing figures of movement. A mental sphere without a body, thinking without movement in the embodied mind without substrates and correlates is impossible.

Back to language. Whether thought figures or configurations written, gestured or danced: if they function as a *sign*, or a system of signs, a language can be assumed. *Signs embody models, and models act as signs.* Sets of signs describe complex phenomena using a complex language. They relay on basic formal sets of sign elements,

on a base syntax and on a basic semiosis. Logics and mathematics provide model languages to ground a general *formal* base, *syntax* and *semantics* (Rapoport 2009). To remind: The origin of *semiosis* goes back to *coding* (Barbieri 2007); survival and development fostering the rise of *intentional* meaning systems.

3. Movement, Rhythm, Learning and Transfer

Life is essentially movement, controlled, intentional and (pre-)conscious. In its outlines the *body* resembles the dimensions of *physical relations* and figures (biophysics); *movement* embodies their *dynamics*. Dynamics imply *control*: position in space-time, intent held, procedure resulting, potential open and strategy conceived. When branching into networks a straight line leads from relations to embodiment, to movement and movement control constituting life systems. Control of life processes asks for *informational* representations, proliferating with the nervous system and the brain towards as well *central* as *distributed* control. Representational language develops (Bickerton 1990), in all *sensory* domains, towards to control of inner and outer environments. *Embodiment*, and, in sequel, *movement*, essentially also shape *control systems* by the material systems to be controlled and by their physiological substrates,. Muscles physiologically rely not only on reflexive via the spine and conscious control. Decisive control loops use direct physiological *feed back* and *self- organisation* in actual control processes. *Control* is *distributed* into fine detail and networked often be direct mechanical/physiological feedback. Robotics use such insights into formal models yet fully to be explored. Not surprisingly movement influences thought processes, energetically and most likely also through logic figures and semiotic shapes. Movement and thinking are intrinsically formally and analogically connected. Yoga, rune exercises, dance and rhythmic (!) gestures depicting geometrical figures ground on movement controlled.

Movement –as life - is governed by *rhythm.* Rhythm marks the transfer from static relations to dynamic movement. *Frequency* modulates and shapes rhythms into ever more complex patterns conveying meaningful life structures. *Distance* in terms of space and time is filled in by a positioning act or an event leading from the one point to the other. *Curves* indicate change, mark constraints, transitions or amplitudes or condense complexity as in phase space representation. As a status at point A will differ from that at point B, so will the life potential remain steady on the 'move'. When the formal determinants of the rhythm change, so will its dynamics.

Geometry depicts rhythm in curves, mathematics does so in non-linear functions.

Close formal relationships connect *movement, rhythm, , geometry* and *measure. They do so in all media: lights, sound, touch, magnetism and not yet detected ones*. For example: by rhythm *touch* is perceived through the eyes of the observer in a syn-aesthetic mode when sweeping the eyesight over a *sculptural* form. Rhythms are inherent in *colour,* physically representing *frequency patterns* (as sounds do), in psychological states of mind as in *mood.* Rhythms act as signals. Rhythms are formed by the *sequence of spaces* in any space pattern as e.g. in a tiled mosque. Dramaturgy is *rhythm of emotion. Art* in all its forms embodies movement and rhythm, as expression

of the artists intent as well as carrier of the communicating language. Art may serve as a paradigm for the impact of rhythms and movement on *perception, observation, cognition* and *feeling*. Deeper still, it indicates the constituting and shaping power of base relations up to the most complex manifestations of higher consciousness as in art and science. Or, paraphrasing R. Steiner (Steiner2010): it should be possible, to employ gestures, signs, forms and colours like language concepts.

In Asian cultures the acts of thinking, and learning, are circumscribed as a *dance*: WuLi, RenLi, ShiLi. Dance symbolizes *recursiveness, recurrence*, a *helix* of questions and answers changing with each turn of the gyre. Dance expresses self-reference, free dancing conveys *self-organization, autopoiesis*. The act of conceptualisation as a dance underfeeds *learning* as a basic, if not the essential process of life. It can be conceived as the gradual *differentiation*, a *branching of archetypes* in *representation and thought*. Learning arranges into order the variety of life phenomena observed towards be represented, ordered and stored for further intentional use. In toto all images build a structured representation of the world as perceived and co-acted with, *enacted by the* uno actu *learning* individual or the learning societal unit. It suggests that learning bases on relational and conceptual archetypes and follows archetypical procedures.

Knowledge needs be available, *disposable* knowledge to be employed freely. To that end knowledge has to be ordered in ways related to *practice:* e.g. as a theoretical frame of *models,* a *toolbox*, and a set of *experiential cases*. All three modes of order contain models, preferably simple (not simplistic) models. In learning practice they are directly related to fundamental models derived from *systems and systemic* thinking. *Autopoietic and performance* models for human institutions provide a focal example. Within a defined knowledge area such models may constitute a *model alphabet, a model tool box* and preset the rules for their use as a language of higher order. Mental constructs rest on such formal languages carrying symbolic meaning

4. Representation (For-) Casting Anticipation

Research on anticipation in life systems spawned *anticipatory computation*, the mathematics and the physics of *anticipatory systems.* (Dubois 2001). Anticipation might in addition be traced back to base logic and to *systems thinking*. Existence and life as observed emerge and proliferate in space and time. When changing they follow the arrows of time dominated by the laws of physics and the logics behind. To persevere a life system has to develop *ultra-stability*. It does so by anticipation, *relying on the continuous validity of the rules in logics and physics* and the principles of evolvement inherent. They likewise bank on the relative stability of the key features of *types of structure and organisation*: biological or a social systems. Anticipation is possible only so far as (dynamic) stability can be counted upon. Anticipation lies at the core of the evolvement of life driven by rising complexity and semiotic networking. During the course of evolvement it is subjected to non-linear (formal) occurrences as *bifurcation, phase transitions* and e.g. *chaotic phases*. The formal rules of complexity dynamics scaffold anticipation. In terms of complexity dynamics the phenomenon of Life appears an intentional *complex adaptive system (CAS)*. Life co-acts and co-develops with its

equally complex adaptive internal and external environments. Anticipation therefore is part of the rules of CAS and of complexity dynamics. In reverse, complexity can be coped with only when the course of development is sufficiently foreseeable, using the foresight to set constraints and to focus by evaluating and targeting. To meet challenges life developed a *'simplicity out of complexity'* in behaviour, to be found in the individual as well as on the group and institutional societal level. Enforced by *natural selection*, the behavioural, 'handling' simplicity founds any life systems.

Pre-forms of anticipation can be seen in the *primeval coding* during the pre-forming phases of life evolvement. In the next step the evolving *memory* stored past courses of history, *extracted rules* from experience and *attached meaning* to them. Survival and development acted as general constraint and intent. Anticipation of what could and what ought be proved to be on of the necessary preconditions to sustain and to multiply life in changing environments. Supposing unchanging basic relations it needs be assumed that the rules determining the past would *not diverge* essentially from those to be expected in the foreseeable future. Allowing for complexity and the general uncertainty, thus *memory* provides a structured *probability* field of likely events. Assessing from internal value scales, intention and targeting evaluate the existing potentials/ probabilities and decide action. - The outcomes of live anticipatory 'computing' are transferred into complex behaviour at surprisingly early stages in evolution. While the blob of protoplasm called amoeba owns but few parameters directly responding to stimuli, already birds (e.g. ravens) and elaborately mammals show long range *strategies*. Interspecies correlations as in symbiosis or predator-prey co-operation demonstrate for example that the base life resources are exploited but within the limits of recycling and recovery. The policy again precludes *anticipation transferred into intentionality*. The *anticipative strategy* 'Live and let live' develops early in evolution.

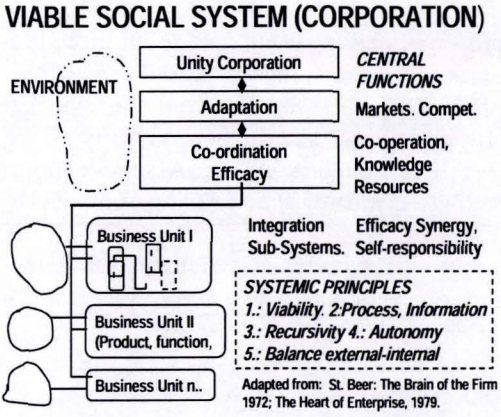
Anticipatory systems are most complex systems. They reflect the intricate complexity of decisions when preserving and proliferating life grounding on faculties to anticipate 'realistically'. They permit to *abstract quasi-statistically recurrences* and *rules* that apply for immediate operational reaction in a frame of tactic and strategic response, meaningfully networked. Necessarily *anticipative memory* contains programs covering the full *circle/helix of control*: orientation, evaluation and targeting, planning for measures, implementation and operation control. The actual as well as the relevant *potential complexity increase* needs be cared for. Operationally economizing, simplicity is assured by intricate feed back systems. *Universals* in the operation of anticipatory controlled systems suggest *anticipatory universals to be further explored.*

5. Patterns in Modelling Supporting Pragmatic Heuristics

The qualities of anticipation as means of *heuristics* are employed in planning and control. Whether in reality or thought experiment, the receipt remains the same: vary a model existing in memory, adapt it to targets, and test its usability. The above example of the scientist struggling with a paper is but one of many. The crucial aim is to make the idea's *eigen-logics* shape the thought process *without loosing control.* To assure the effect is decisive for any learning effort. It is the eigen-logics on different levels and

memory environments that makes learning last and integrates learned items into the appropriate memory context: ultra-short, short and long-term.

Figure 3 indicates much simplified models of a societal *institution* depicted as a viable system (Beer), and a *performance process* (input-output system) within such an institution. Figure 4 adds the relating performance process. Both models base on the input-output concept as opposed the autopoietic one. Using simple geometrical sign elements they construct a representation aligning these elements with meaning. They can be used for demonstration, explication, application to experiences, for *heuristics* e.g. asking to differentiate the models into more detail. Actually such models were employed in he classroom to stimulate and visually to ground a learning dialogue.



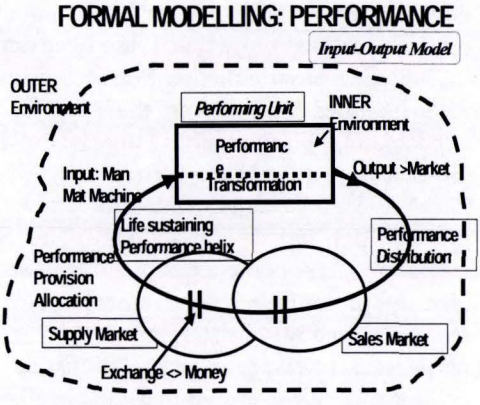


Fig 3 Viable Social System (Corporation)

Fig 4 Formal Modelling: Performance

Simple sign elements a e.g. the line and the *curve* resemble not only relations. Extending their perception as but *static* graphic constituents they may be evaluated as representation of *movements*. By memory and intent movements are connected to meanings. For example a *point* as set by the observer may delineate a departure to a sequence or a sign for *non-dimensionality*. Or it may simply separate. In contrary a *line* marks 'quelque chose etendu'; it not merely separates, but creates a one-dimensional *distance (*Roehle1973): A *curve* indicates a third dimension; closed in a circle or a helix it presents *directed movement* in space and time. It may signify openness, closedness, or finiteness. A *graph* denotes direction, the *node* crossing. Graphic *figures* are *patterns* to attract meaning and to express meaning. Alphabets have been arisen that way: the one we use, the rune alphabet and intent specific ones. Iconic units e.g. as in Chinese have been simplified to an array of simple patterns. The Cabbala builds a system based on the interrelationship of the numbers 1 to 10 interpreted for meaning. In Asia the 'Holy Geometry' constitutes a complex geometric language to describe the world. Using six simple sticks, I GING is used for *divination*. I GING grounds in Boolean algebra. It seems that such simple patterns are used to evoke subconscious patterns in the observers mind inducing them to observe, to remember and to remind what is pre-conscious or suppressed. Its not so much magic than psychology of archetypical forms.

Sign elements, figures, patterns, partitions numbers, – the enumeration bypassed shapes. *Shapes* occur namely in the forms of *symbols, or icons,* are patterns carrying meaning, intent and purpose. Shapes are situated at the *threshold between science and culture* They are designed to *transfer*, both physically and non-physically, complex information and/or energy or both. (Shapes often resemble biological or technical antennas tuned to specific life frequencies as to mating). From biology to the use of icons in traffic signs and passengers guides in airports to notably magic rites, they are ubiquitous in any environment. Archetypes of meaningful patterns are known from the systems sciences to Vodoo practices. In particular the religions use an elaborated language of symbols. Now wonder the more rational understanding of religion in Reformation opposed symbolic representations and eventually burnt them.

6. The Life Dance of the Simple with the Complex

Again: live systems are anticipatory systems. Based on memory they store patterns/signs and the meaning attached to. From past experience they assess the actual situation and probable futures. The continuing learning process actively *adapts anticipative memory* to changing *inner/outer environments*. That assures the *efficacy* and *continuity in change* basing anticipation. The above mentioned discontinuities as *bifurcation and phase tran*sitions follow rules, i.e. that of complexity dynamics. *Selection* decides whether a life system will evolve or disappear; *de-volution* is counterpart of e-volution. Evolution can be seen driven by and formed by the interaction of complexity dynamics and semiosis dynamics. Ever more differentiating and complex structures compete for the available life sources while fighting for option/action spaces. Life systems attach meaning to opportunities, spaces and probabilities for survival and development. Therefore the control networks of life systems recognize their environments as an intricate system of meaningful signs. Patterns, structures, sequences and constellations are assessed as potential stimuli to respond to or to exploit..

Simplicity is situated at a higher level of *control networking*. The elaborate *hierarchy/ heterarchy* of life systems as seen from evolvement and branching, from networking and distributed control, provides the space for *behavioural simplicity of complexity*. Simplicity is possible since the *basic patterns* dealt with afore *govern even most complex structures*. On each level of complexity simplicity is regained by *re-enfolding process* following these (nearly) universal relations, patterns, structures, sequels which determine the behavioural space of any life system. Complexity, driven by meaningfully enaction of life, is forced to find back to simplicity on the actual complexity level. Simplicity out of complexity *shapes signs and the sign systems*, which govern in turn the processes of *anticipation and learning*.

A first step appears the further study of signs concerning their comprehensive constitutional impacts to social/societal life systems. Signs are essential for any human thought process: for perception, expression, recognition, evaluation, learning, believing; for anticipation and action control. Their gradual development is closely connected with the raise of language, of culture and with the complexity of civilisation. Signs, literally, represent the map. Studying the map helps to understand and to explore the territory.

7. Conclusion Epilogue: Principles, Models and Signs for Learning

The initial simple topic led into a complex landscape. The paper intended do highlight the influence of rules pervading human co-action with her/his world. Virtually there is no aspect of human perception, thinking and acting which is not affected.

The paper arguments on the boarder of science and yet in the centre. Science means exploring as to guide the human in its entirety, body, mind, soul, spirit. Knowingly the text steps on quicksand. Grounded speculation is part of science; it keeps science open and creative. A but mosaic picture intents to evoke queries. Epistemology has not been dealt with; in particular the role of analogies as the original mode of reasoning needs be discussed. Approaches similar to these can be found already with classical philosophers. Well known are *scholastic* attempts as that of the medieval Monk Raimondus Lullus. Today it is software and robotics not relying on computers and AI only, but on the intricate connections between embodiment, movement and thinking as described here. It rests on formal modelling and simulation of extremely complex societal phenomena. AI struggles for new approaches returning to brain research. Computers and their software are questioned anew as to their qualities. Learning, work techniques, creativity, innovation (the author has been teaching life long) etc. make extensive use of formal relations. So does related software e.g. mapping mind processes.

On superficial contemplation the knowledge gained seems trivial. It reminds and corroborates that the world originated from most simple relations following basic logic and meaning attached. It evolved following simple principles, differentiating, branching, changing. Specialisation often lost the connection to the shared formal base and with that a powerful research tool. Hopefully the paper contributes to the discourses searching sophisticated answers on a transdisciplinary footing.

Acknowledgement: Author's Note

The topic comes broad, facing the dangers connected with a formal and general approach. At the present state of research, the attempt resembles partly a game of glass beads, partly a non-complete mosaic, a yet scattered network. Its argumentation asks for formal retracement and on that base for a material and comprehending view. The diversity of aspects leaves interfaces to be specified, bridges to be built and connections to be secured. The paper aims at stimulating continuation, enrichment, complementation and the critical dialogue. – References had to be cut down to a minimum; not diminishing the author's debt for acknowledgement and gratitude.

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