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What is Systems Science?

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Abstract

A most natural view is that systems science is a science dealing with systems and their systems properties. What, then, is science that it can deal with systems properties which by nature are deeply penetrating also into the systemic nature of our conceptual processes, of language, and of science itself. We start out from an independent view of the concept of science. Namely, that sciences are *deductive* in the sense that the *results* of scientific activity are *deductively presentable* as in descriptive theories. This is what allows wide *communication* of scientific propositions, necessary for their accessibility, examination and tests by other scientists, eventually to be intersubjectively accepted. On the other hand, *the scientific activity* is in general a process which is beyond full deductive description. We examplify a tendency. The more introspectively oriented the domain of inquiry for a science is, the more difficult is it to isolate the deductive-result part of a science from the scientific activity. A *systemic view of science* arizes with science referring not only to the deductive-result part of science but also to the scientific activity. We make it explicit that "science" in "systems science" be systemically conceived, and develop the concepts of *systems science, general systems*, and *system*, accordingly.

1 What is science?

Sciences are *deductive* in the sense that the *results* of scientific activity are *deductively presentable* as in descriptive theories. This is what allows wide *communication* of scientific propositions, necessary for their accessibility, examination and tests by other scientists, eventually to be intersubjectively accepted.

On the other hand, the scientific *activity* is in general a process which is beyond full deductive description. In other words, scientific processes may well be beyond scientific description. This is sometimes understood with reference to the *inductive* nature of producing scientific hypotheses and a general agreement on *induction as beyond deduction*.

This *activity/result* distinction (or induction/deduction distinction) for science is not always appreciated, however, which easily causes confusion as to what science really is. It frequently happends that scientific thinking becomes identified with deductive thinking – and science with *deductive science*. If so, the fundamental question of where the axioms (on which the deductive scientific processes build) come from, are neglected as "non-scientific" or, if considered, dealt with in *foundational research* for the deductive science.

This situation prevails also for mathematics and logics as deductive disciplines. In the following two quotes (notably the last paragraph of the first), we see how mathematicians (barely) may manage to avoid foundational questions in trying to isolate mathematics as a purely deductive discipline.

> [**Mostowski A**, 1966, page 140] "The abstract set theory has contributed more than any other branch of mathematics to the development of foundational studies. The reasons for this phenomenon are numerous.
> One of the basic assumptions of set theory is the axiom of infinity which says that there exist infinite sets. This assumption implies that the scale of infinte cardinals is itself infinite. Thus the axiom of infinity leads us out of the mathematical domains which are close to everyday practice and even to scientific experience. We are thus faced at the very beginning of set theory with the fundamental question of the philosophy of mathematics: which mathematical objects are admissible and why? ...
> Most mathematicians do not perceive the

problem which is posed by the abstractness of set theory. They prefer to take an aloof attitude and pretend not to be interested in philosophical (as opposed to purely mathematical) questions. In practice this simply means that they limit themselves to deducing theorems from axioms which were proposed to them by some authorities."

> [**Whitehead and Russell**, 1962, page v] "We have, however, avoided both controversy and general philosophy, and made our statements dogmatic in form. The justification for this is that the chief reason in favour of any theory on the principles of mathematics must always be inductive, i.e., it must lie in the fact that the theory in question enables us to deduce ordinary mathematics. In mathematics, the greatest degree of self-evidence is usually not to be found quite at the beginning, but at some later point; hence the early deductions, until they reach this point, give reasons rather for believing the premisses because true consequences follow from them, than for believing the consequences because they follow from the premisses."

Concerning *sciences*, Russell is more outspoken on the role of induction and the induction/deduction distinction.

> [**Russell B**, 1948, page 700] "What these arguments [referring to Hume] prove – and I do not think that the proof can be controverted – is, that induction is an independent logical principle, incapable of being inferred [deductively] either from experience or from other logical principles, and that without this principle science is impossible."

It is interesting to see how Russell here (and nowhere else, as far as we know) looks at induction as an independent *logical principle*. Still, he is not alone. Another similarly tolerant view is the following of van Benthem:

> [**Van Benthem J**, 1982, page 435] "Logic I take to be the study of reasoning, wherever and however it occurs. Thus, in principle, an ideal logician is interested both in that *activity* and its *products*, both in its *normative* and its *descriptive* aspects, both in *inductive* and *deductive* argument. ...
> An enligthened logician like Beth, for instance, realized the danger of intellectual sterility in a standard gambit like separating the *genesis* of knowledge in advance from its *justification* ...
> [page 450] ... theories as scientific *activities* rather than *products* of such activities are not irrevocably outside the scope of logic. ...
> In the semantic perspective too, there is room for pragmatic studies. E.g., model theory presupposes that successful interpretation has taken place already. How? ...
> ... these references are only the first landmarks in a hopefully fruitful new area of logic."

It is our definite impression that logics, as a deductive discipline, has today received such a general acceptance, that it is far more advisable, and natural, to leave it as such – and, instead, broaden the concept of *language* to have it include the inductive description and interpretation processes.

Whether science is conceived *deductively* or *systemically* (not in isolation from its foundations or genesis), it is bound to have its results presented deductively – for reasons of communicability. Communicability is necessary for intersubjective acceptance of scientific "truths" (and their presuppositions – if revealed). Communicability, in turn, presupposes language. How is this concept to be conceived?

2 What is language?

With respect to common understandings, language has fared less well than logics. Let us recall some selected historical notes from logics and philosophy of science leading to our systemic conception of language.

In a disciplinary account of logic, as in mathematical logic, the concept of language is either not defined at all, or is considered as partly outside the domain of the discipline. Compare Shoenfield's book on mathematical logic:

> [**Shoenfield J**, 1967, page 4] "We consider a language to be completely specified when its symbols and formulas are specified. This makes a language a purely syntactical object. Of course, most of our languages will have a meaning (or several meanings); but the meaning is not considered to be part of the language."

Shoenfield's honest account of his disciplinary approach indicates how the fragmentation into mathematical logic "makes" language devoid of meaning. This is a clearly distortive approach, or a high price to be paid for mathematical clarity.

Also in a wider, philosophical linguistic context, admitting meaning as part of language, the fragmentation problem is apparent:

> [**Putnam H**, 1975, page 215-216] "Analysis of the deep structure of linguistic forms gives

> us an incomparably more powerful description of the *syntax* of natural languages than we have ever had before. But the dimension of language associated with the word 'meaning' is, in spite of the usual spate of heroic if misguided attempts, as much in the dark as it ever was."...
> In my opinion, the reason that so-called semantics is in so much worse condition than syntactic theory is that the *prescientific* concept on which semantics is based – the prescientific concept of meaning – is itself in much worse shape than the prescientific concept of syntax."

In *semiotics*, sometimes referred to as the science of language, there is an explicit recognition of *syntax* and *semantics*, as well as *pragmatics*. In [Carnap, R, 1942, page 9] it is proposed that the three parts, syntax, semantics, pragmatics, constituting the whole science of language, can be individually understod. In [Löfgren L, 2000, page 18] we argue that such a fragmentation is untenable. The argument is based on language being a holistic (genuinely systemic) conception. It has to be complementaristically comprehended.

> **Language**, in its general systemic conception, is a whole of complementary description-interpretation processes. Complementarity refers to holistic situations where (a classical) fragmentation into parts does not succeed. In its complementaristic understanding, the phenomenon of language is such a whole of description and interpretation processes, yet a whole which has no such parts fully expressible within the language itself. Instead, within the language, the parts are complementary (entangled) or tensioned. There are various related ways of looking at this *linguistic complementarity*:
>
> (i) as descriptional incompleteness: in no language can its interpretation process be completely described in the language itself;
>
> (ii) as a tension between describability and interpretability within a language: increased describability implies decreased interpretability, and conversely;
>
> (iii) as degrees of partiality of self–reference (introspection) within a language: complete self–reference within a language is impossible;
>
> (iv) as a principle of "nondetachability of language".

By comparison with Carnap's fragmentation of language, we thus understand language as a whole by complementaristic comprehension. The syntax and semantics parts correspond to the complementary description-interpretation processes, and pragmatics to the processual nature of the description-interpretation processes. However, while Carnap thinks of a classical fragmentation in the three parts (syntax, semantics, pragmatics), we recognize a necessary entanglement of them.

Languages may change and evolve, and with them their capacities for describing and interpreting. Yet, at each time that we want to communicate our actual knowledge, even on the evolution of language, we are in a *linguistic predicament*, namely to be confined to a language with its inescapable complementarity.

As explained in [Löfgren L, 1992] we have argued the validity of the linguistic complementarity from the functional role of any language, namely to admit communication or control.

> **Presupposition for language**. *Descriptions* (sentences, theories) are always *finitely representable* (in order to be transmittable in a terminating communication) and locally independent of time (remaining fixed for as long as the description is being used as description, i.e., is being transmitted in communication, is being analyzed and interpreted).

3 On von Bertalanffy's unification goal for general systems

The concept of *general system* was conceived by von Bertalanffy in the hope of coming to grips with the disciplinary fragmentation of science.

> [**von Bertalanffy L**, 1968, page 30]. "*The Quest for a General System Theory.* Modern science is characterized by its ever-increasing specialization, necessitated by the enormous amount of data, the complexity of techniques and of theoretical structures within every field. Thus science is split into innumerable disciplines continually generating new subdisciplines. ..
> It is necessary to study not only parts and processes in isolation [as in classical analytic scientific methods], but to solve the decisive problems found in the organization and order unifying them, resulting from dynamic interaction of parts, and making the behavior of parts different when studied in isolation or within the whole."

Although von Bertalanffy apparently had sweeping ideas of concepts like *theory* and *science*, his intuitions were remarkably foresighting. Notably concerning the difficulties of having "systems science" develop in a way not itself subject to fragmentation.

[**von Bertalanffy L**, 1968, pages vii-viii]. "The student in 'systems science' receives a technical training which makes systems theory – originally intended to overcome current overspecialization – into another of the hundreds of academic specialities. Moreover, systems science, centered in computer technology, cybernetics, automation and systems engineering, appears to make the systems idea another – and indeed the ultimate – technique to shape man and society ever more into the 'megamachine' which Mumford (1967) has so impressively described in its advance through history."

Under a section *General System Theory in Education: The Production of Scientific Generalists* he writes:

> [**von Bertalanffy L**, 1968, page 49]. "Conventional education in physics, biology, psychology or the social sciences treats them as separate domains, the general trend being that increasingly smaller subdomains become separate sciences, and this process is repeated to the point where each speciality becomes a triflingly small field, unconnected with the rest. In contrast, the educational demand of training 'Scientific Generalists' and of developing interdisciplinary 'basic principles' are precisely those general system theory tries to fill. They are not a mere program or a pious wish since, as we have tried to show, such theoretical structure is already in the process of development. In this sense, general system theory seems to be an important headway towards interdisciplinary synthesis and integrated education."

In our view, the question is if "scientific generalists" can at all be trained in a university curriculum – where communicational demands require communication to be centered around deductively presentable *results*, necessarily leaving behind large parts of the (inductive) activities leading to the results.

The problem is the same as if foundational research could be trained in an orderly fashion. In our view, foundational insights could be expected first at senior levels, *after* having acquired disciplinary knowledge.

By way of another example of von Bertalanffy's systemic insights, let us quote as follows.

> [**von Bertalanffy L**, 1968, page 238]. "It may be mentioned, in passing, that the relation between language and world view is not unidirectional but reciprocal, a fact which was not made sufficiently clear by Whorf. The structure of language seems to determine which traits of reality are abstracted and hence what form the categories of thinking take on. On the other hand, the world outlook determines and forms the language.

A quite plausible observation. In particular we notice von Bertalanffy's broad conception of language. Yet, apparently not developed all the way to its systemic conception, and not recognizing its ultimate, unifying presupposition (cf section 2).

4 On Klir's view of systems science

In his writings on systems science (by way of a small sample, [Klir G, 1991; Klir G, 2001]), Klir starts from a common-sense definition of system, whereby:

> "the term *system* stands for *a set of things* and *a relation among the things.* Formally, $S = (T, R)$, where S, T, R denote respectively a *system, a set of things*, and *a relation* (or, possibly, a set of relations) defined on T."

Klir points at the simplicity of this definition as its weakness as well as its strength.

> "The definition is weak because it is too general and, consequently, of little pragmatic value. It is strong because it encompasses all other, more specific definitions of systems. Due to its full generality, the common-sense definition qualifies for a criterion by which we can determine whether any give object is a system or not: an object is a system if and only if it can be described in the form that conforms to $[S = (T, R)]$.
> Once we have the capability of distinguishing objects that are systems from those that are not, it is natural to define systems science as *the science whose objects of study are systems.*"

Consider the stated presupposition for the proposed systems science definition, namely that "we have the capability of distinguishing objects that are systems from those that are not". What if we don't have such a capability? Shouldn't this problem then be *within* the domain of systems science, i.e., be a systems science problem!

Compare Cantor's common-sense conception of a *set* as a collection of definite, distinguishable objects of our intuition or of our intellect to be conceived as a whole – referring as it obviously does to a person conceiving the whole in his inner cerebral language *and* requiring translatability to an external communication language in order to secure intersubjective acceptance. Compare how the latter requirement leads into deep foundational studies which gradually matures in actual set-theories (whose axioms cannot be fully understood if isolated from the foundational domain; compare the Mostowski-quote in section 1).

Compare *computer science* and the problem of identifying the computable functions. This identification cannot be done by computers alone, but requires foundational aids – which are often included in the concept computer science (thus a systemically conceived science).

Also in quantum mechanics, as a physical science, we see hints at a systemic conception. From [Busch, Lahti, and Mittelstaedt, 1996] we quote:

> "The quantum theory of measurement is motivated by the idea of the universal validity of quantum mechanics, according to which this theory should be applicable, in particular, to the measurement process. Hence one would expect, and most researchers in the foundations of quantum mechanics have done so, that the problem of measurement should be solvable *within* quantum mechanics. The long history of this problem shows that, in spite of many important partial results, there seems to be no straightforward route towards its solution. This general impression is confirmed in the present work by means of a number of no-go-theorems."

We have not seen Klir embark on foundational questions for justification of his above systems science presupposition. We do not think that his concept of science, in systems science, is systemically conceived, and not that his concept of system is wide enough to permit natural introspective system-inquiries.

5 Systems Science, General Systems, and System – systemically conceived.

With reference to the systemic nature of our linguistic comprehension processes (sections 1 and 2), we argue the basic systems-concepts as follows.

Systems Science *is to be systemically conceived.* That is, systems science should not (and could not in general) be isolated as in referring only to the deductively presentable results of systems research – but should be allowed also to refer (in an inductive vocabulary) to the very activity of systems research.

This, in general, requires a shift from theory, logic, science – conceived as deductively presentable disciplines – to systemic language as the natural background for *systems research* as a *foundational activity.*

General Systems, focusing on the property of being systemic (paradigmatically present in language), may well *be identified with systemic language* (as a whole of complementary, or entangled, description-interpretation processes).

System, finally, is (as usual) regarded as a whole of interacting components (parts) – with the (not usually stated) qualification: *conceivable as such in a shared language.*

Without the last qualification, we may be in danger of violating *the principle of "nondetachability of language"* (view iv of the linguistic complementarity) – easily causing difficulties in introspective systems contexts.

6 Hints at applications

We have argued a shift in attention, from the deductive scientific disciplines to the systemic concept of language, in order to come to grips with problems inherent in a one-sided classical focus on the deductively presentable results of scientific activity (as if fragmentable from the activity itself). Let us hint at some applications of this systems move.

6.1 Unification of fragmented disciplines

As mentioned in section 3, von Bertalanffy conceived of his concept "general systems" in the hope of coming to grips with the disciplinary fragmentation of science. At the same time he was aware of a fragmentary development of general systems itself.

Moving to the systemic concept of language as paradigm for general systems (section 5), we notice that it is unifying, first in the sense that it obtains for several species of language, from genetic language, over formal languages, to external communication languages. Further, our actual shared communication language is unifying in that all communicable knowledge depends on it. Knowledge in various scientific disciplines, even if in distinct languages, is unified in the common presupposition of the linguistic complementarity (section 2).

Let us expand on systems research, as foundational activity (section 5), as unifying. Foundational research, as search for founding scientific truths, often itself leads to fragmented foundational disciplines. This is due to the contextuality of the semantic truth concept.

However, there is another approach to foundational studies, namely in a succesive revelation of presuppositions, intimately tied to view i of the linguistic complementarity (see [Löfgren L, 2002]). This is unifying in that it ultimately will lead to the presupposition for the linguistic complementarity.

Beside unifying understandings of fragmented scientific disciplines, we have unification in interdisciplinary domains, notably in systems engineering. For example, in the Hubble telescope system, various sciences *meet* in its construction.

6.2 Gödel's revision of Formal System

Attempting to answer the question what a system is, [Rosen R, 1986] compares the concept of system with that of set. One of his comments is: "since the axiom systems in terms of which set-ness is characterized are themselves *systems*, it may well be that attempts to define systemhood in terms of set-ness is cart before horse".

Of particular interest here is that Gödel, in his fundamental papers from the early thirties defined the concept of formal system (the axiom system to which Rosen refers) by means of a concept of "finite procedure". And that Gödel in 1965 made a revision of his concept of formal system, namely by replacing "finite procedure" by that of a Turing machine. As explained in [Löfgren L, 1992], we look at this as a first embryonic step from formal system to systemic language (a full step also recognizing the Turing machine as interpretor in a programming language).

In this perspective, Rosen's "cart before horse dilemma" resolves nicely in our conception of system (section 5; with its stated relation to language).

6.3 Linguistic realism

In [Löfgren L, 1977; Löfgren L, 1993] we explain the concept of existence in linguistic realism by referring to the very nature of an inductive linguistic confirmation process. This has vast explicatory consequences.

For example, for understanding the fragmentation problem: is nature in itself fragmentable, and thereby nondistortively fragmentable, or, is it our linguistic description processes which make nature appear fragmentable?

Again, for understanding the "intended interpretations" problem, with its sources in the Löwenheim-Skolem theorem, central within current inquiries into "the limits of logic" – and possible resolutions after taking the step into a shared systemic language ([Löfgren L, 2002].

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