The New Science of Cybernetics: A Primer

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Four years after the publication of the first volume on the new science of cybernetics (NSC) (Müller, 2009) and after two more books on NSC (Müller, 2011, 2012) it is time to present and to summarize the main features and characteristics of the new science of cybernetics within a single article.

- Historically, the new science of cybernetics can be viewed as a potential outline of Heinz von Foerster's vision of second-order cybernetics as the science of observing systems or, alternatively, of living systems by living systems for living systems. Heinz von Foerster introduced the concept of second-order cybernetics on several occasions, without specifying, however, its content and cognitive organization (Foerster, 1974, 2003)
- Systematically, the new science of cybernetics operates on a new level which, not quite unexpectedly and surprisingly, can be characterized as second-order level. This second-order level is self-reflexive by nature and by design, because this level comes into play whenever a concept, a model or an academic field turns onto itself, like in understanding understanding or in cybernetics of cybernetics.
- Functionally, the new science of cybernetics can be viewed as a trans- or post-disciplinary second-order field for navigating through an ocean of first-order level science. NSC operates primarily with objects or with operations from first-order science and transforms them into new components which exhibit strong comparative advantages in terms of novelty and robustness.

This list of historic, systemic and functional features of the new science of cybernetics(NSC) may look strange or incomprehensible at first sight. It will become, thus, the main purpose of this article to transform these seemingly vague and unclear descriptions into concise ones which readers with only a weak familiarity with the old science of cybernetics can understand. Eventually, even the short set above of critical characteristics of the new science of cybernetics should change into a clear overall summary of NSC, once a reader has finished this article and turns, once more, to its beginnings.

1 The Old Science of Cybernetics as a Point of Departure

Table 1 summarizes several of the core-features of the old science of cybernetics as the field evolved from the late 1940s to its rapid decline in the United States during the 1970s. This steep decline did not occur on cognitive grounds and on a growing number of Kuhn-type anomalies, but due to changes in funding regimes and due to the rise of other trans-disciplinary research traditions like the cognitive neuro-sciences or Artificial Intelligence.

Table 1 First-Order Cybernetics as a Starting Point

Categories	First-Order Cybernetics
Domains	A Transdisciplinary Field for Natural, Technical and Social Systems Steering, Controling of Technical, Natural or Societal Systems Emphasis on Information and on Information Technologies Main Emphasis on Strong Forms of Control Central for Control, Communication in Natural and Social Systems
Level	First-Order Level Research
Epistemology	On Systems Observed No Relevance for Self-Reflexivity Observer Excluded from Research Designs

The term cybernetics was initially formed as a nominalized Greek adjective *κυβερνητικός* („steersman-ish",,"mate-ish"), which results from a blending of two Greek words, namely *κυβερνήτης* (steersman, mate, navigator) and κυβέρνησις, (control, command, rule). Thus, the old science of cybernetics was understood and defined in Norbert Wiener's path-and field breaking book from 1948 as the science of control and communication in the animal and the machine which, initially, left out the area of humans and human societies which were brought in in Wiener's "The Human Use of Human Beings" (Wiener, 1954) six years later.

From Table 1 one can see that cybernetics evolved as a trans-disciplinary field with a special emphasis on control and regulation and developed a growing number of cybernetic electronic machines and vehicles, an impressive number of general principles, especially W. Ross Ashby's "law of requisite variety" (Ashby, 1956). Epistemologically, the old science of cybernetics was characterized by the mainstream perspective of a hypothetical realism and was controlled by traditional rules like objectivity, induction or causality.[1]

When Heinz von Foerster started to use the term second-order cybernetics as the science of observing systems and qualified traditional cybernetics as first-order and as a science of systems observed it was far from obvious how, why and where this *scienza nuova* could operate. And at this point the new science of cybernetics sets in.

2 The New Science of Cybernetics as a Trans- or Post-Disciplinary Field at the Second-Order Level

Modern science evolved, for centuries implicitly and since the 19th century explicitly, in a three-layered configuration between research domains proper at a first-order level, supporting research infrastructures at the lower or zero-order level and an area of self-reflexive analyses on scientific research processes at the upper or second-order level.

- The first-order level of research is designed, on the one hand, for the exploration of the natural and social

[1] At various points, Heinz von Foerster characterizes the scientific method with the postulate of objectivity: "The properties of the observer shall not enter the description of his observations" (Foerster 2003:285). However, he adds two more rules which lie in the core of the scientific method:
(i) Rules observed in the past shall apply to the future. This is usually referred to as the principle of conservation of rules …
(ii) Almost everything in the universe shall be irrelevant. This is usually referred to as the principle of the necessary and sufficient cause (v. Foerster 2003:203).
Resting on these three pillars, Heinz von Foerster concludes that the scientific method is "counter-productive in contemplating any evolutionary process, be it the growing up of an individual, or a society in transition." (*Ibid*:204p.)

worlds as well as for the construction of a technological sphere and, on the other hand, for the axiomatization and ordering of the possible worlds of logic, mathematics and related normative fields. First-order level of research constitutes the reference domain for research activities. Scientific investigations on empirical themes across nature and society, on technical or technological systems or on normative issues in logic, mathematics, statistics, ethics or aesthetics fall all under the category of first-order research.

- The zero-order level of research infrastructures performs the catalytic functions of enabling, of accelerating or of improving first-order level research. These different catalytic functions are accomplished, on the one hand, through large-scale facilities and their production of a rich data variety which contains relevant observations, measurements, data and meta-data for first-order level research and, on the other hand, through a dense information base which is composed of useful bibliometric and scientometric documentations. In principle, research infrastructures are focused, on large-scale observation and measurement facilities and on the documentations and data bases in the field of encoded science information.[2]
- In contrast, the domains at the second-order level become, by necessity, self-reflexive, since they study scientific first-order objects or processes with scientific means and provide both a theoretically relevant heuristic and a control function for research at the first-order level.[3] Second-order research can be organized in a normative and in an empirical manner. On the normative side, the self-reflexive functions are fulfilled by developing general guidelines or rules for rational or best practices for first-order level research or by identifying promising hot spots for first-order level investigations in the overall science landscapes. On the empirical side, second-order investigations improve the quality of normal or first-order research or lead to a deeper understanding of research processes in general.

[2] Coded objects comprise publications, gray literature or citations in the science world, but can be extended to coded genetic information in bio-technology, etc.

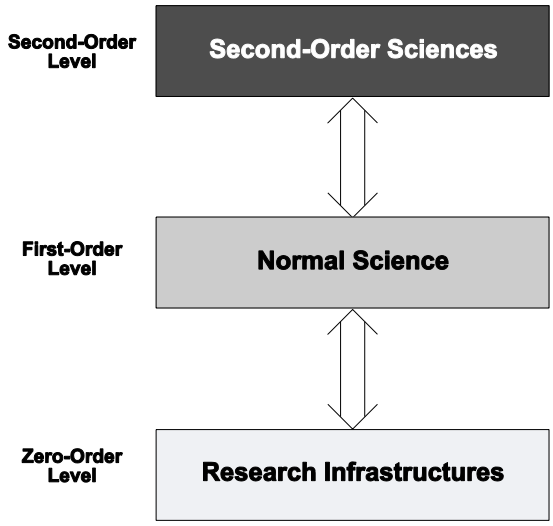
[3] It must be emphasized, though, that self-reflexivity operates on both the second-order and the first-order level.

- At the second-order level self-reflexivity requires scientific research on scientific researchers and their outputs or, more generally, their objects. Sociologists who work sociologically on the evolution of sociological research, for example, operate in a self-reflexive mode at the second-order level. Stronger forms of self-reflexivity are obtained when these second-order sociologists reflect also on their own operations at the second-order level.
- At the first-order level self-reflexivity occurs whenever a first-order researcher operates explicitly on her or his first-order research operations. A sociologist, for example, who specifies her or his goals of first-order analysis, operates in a self-reflexive mode at the first-order level. Additionally, self-reflexivity may be relevant also in the case of phenomenological accounts where researchers describe their own experiences as part of an ongoing research process.

Thus, second-order research becomes, due to its domain of investigation, necessarily self-reflexive whereas first-order research can be conducted either in a self-reflexive or in a non-self-reflexive manner. Traditionally, self-reflexivity was usually excluded from first-order research.

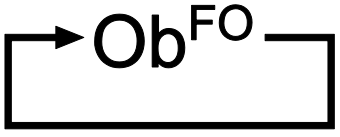
Figure1 summarizes the three layer- or level-configuration for modern science.

Figure 1 Three Levels of Science-Landscapes

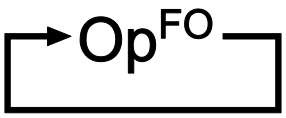


Using Spencer-Brown's self-reflexive notion of re-entry, one can construct two main research domains at the second-order level which become central for NSC.

- The first path leads along a re-entry into the products, outputs or, more generally, into the objects of normal or first-order research Ob^{FO}, including concepts, theories, scientific fields, research designs, methodologies, etc. (Mode I of NSC[4]):



- The second trajectory takes a re-entry into the domain of researchers and their first-order operations Op^{FO}, *i.e.*, a self-reflexive twist towards a deeper understanding of researchers and their recurrent research operations, including NSC-researchers and their operations as well (Mode II of NSC).



From these two different types of re-entries one can derive two different modes for the new science of cybernetics.

- A re-entry into the objects of first-order level research focuses on second-order analyses of first-order level objects like scientific results, data, measurements, concepts, models or research domains. In its Mode I NSC becomes a science of an observing system observing the objects or products of the observing science system. In Mode I, NSC focuses on second-order level analyses of first-order level objects. Examples for Mode I comprise, *inter alia*, theoretical concepts (*e.g.*, the evolution of evolution), theories for a particular field (*e.g.*, a systems theory of systems theory), scientific disciplines (e.g., sociology of sociology, historiography of historiography, logic of logic, cybernetics of cybernetics) or clusters of disciplines (systems theory of systems theory, the cognitive science of the cognitive sciences), etc. Moreover, a re-entry of an observer into first-order level research designs and research methodologies is capable of transforming conventional first-order level research designs into non-standard designs, traditional methodologies into methodologies

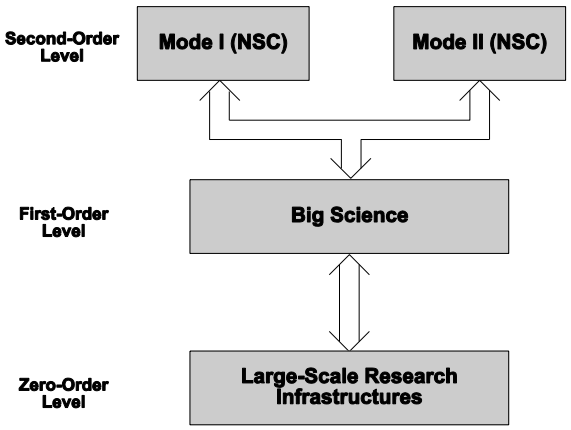
[4] NSC-research on NSC can be considered as a small area within the overall landscape of second-order research. It should be emphasized that within Mode I NSC-research on NSC does not constitute a third-order level, but stays within a second-order configuration.

which are compliant or consistent with NSC and, more generally, normal science first-order level rule systems into non-standard rule systems in accordance with NSC. Thus, NSC in its Mode I becomes also a science of an observing system observing the research designs, the methodologies and the rule systems of the observing science system. Consequently, Mode I of NSC is also responsible for the necessary design and methodology modifications and for the creation of observer-inclusive living research designs and methodologies.

- A re-entry into first-order level research processes centers on second-order investigations of first-order level observer operations. Here, NSC becomes a science of an observing system observing the on-going processes of an observing science system (Mode II). In Mode II, NSC centers on second-order level analyses of first-order level processes. Here, the focus lies on issues like understanding understanding (in a particular domain), learning learning (in mathematics, sociology, etc.), observing observing (in scientific fields like astronomy, biology, etc.), measuring measuring (in the social sciences, in the life sciences, etc.).

Figure 2 presents a configuration for contemporary science landscapes with their three levels, including the two modes of NSC as a field at the second-order level.

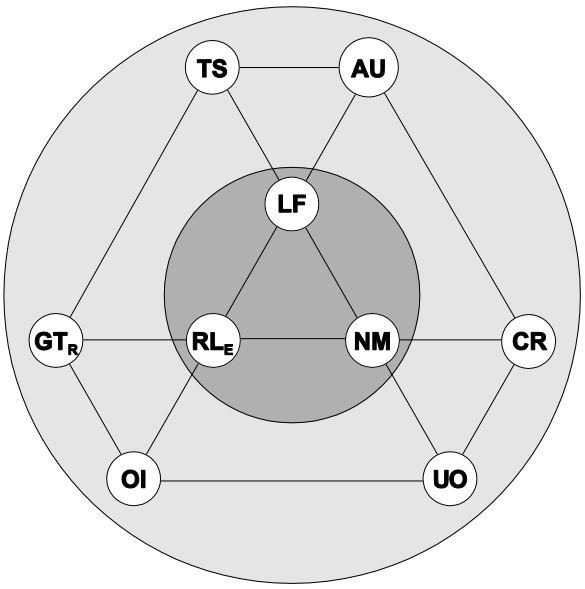
Figure 2 The Three Science Landscapes and the Location of the New Science of Cybernetics (NSC)



3 The New Science of Cybernetics: Its Impact Potential for First-Order Science and Its Cognitive Building Blocks

In terms of cognitive composition, NSC in its two modes can be arranged as a set of densely inter-linked modules or building blocks which can be summarized with the help of Figure 3.

Figure 3 The Cognitive Building Blocks of the New Science of Cybernetics



TS: Triadic Semiology | LF: Laws of Forms | AU: Autology | GTR: Generative and Triadic Relations | RLE: Recursive Operational Language/Eigenforms | CR: Composition Rules across Various Dimensions | OI: Observer Inclusion | NM: Non-

Figure 3 presents these building blocks of the new science of cybernetics with its core area of a recursive, process-based description device (RL_E), a logic of forms (LF) and generative mechanisms (NM) alongside with additional elements relevant for research operations as a second-order field.

The key-concepts of NSC like observers, systems, networks, observing, measuring, etc. have to be constructed in a triadic semiotic web which has been envisioned by Heinz von Foerster in another small contribution, namely in "Computing in the Semantic Domain" (1971). Here, Heinz von Foerster introduces the term "environment" in a triadic and distributed fashion.

'Environment' appears in three distinct domains: in the domain of the 'real world' (W), in the domain of 'cognitive processes' (C), which provide an organism with an internal representation of his surroundings; and in the domain of an organism's 'descriptions' (D) of his world. Environment is the triadic relationship E(W,C,D) between these domains. (Foerster 1971:239)

Apart from the basic triadic configuration E(W,C,D) one can derive three different types of dyadic relationships where the third component becomes implicit. These dyadic relationships comprise the set of E_D(W,C), "determined by an organism's perceptive potential" (*Ibid.*), E_C(W,D) "determined by the organism's behavioural potential" (*Ibid.*) and, finally, E_W(C,D) "determined by an organism's cognitive potential" (*Ibid.*) [5].

Subsequently, the domain of cognitive processes C will be substituted by the more abstract notion of an observer or operator O so that any concept C is to be structured in the form of C(O,W,D). More generally, the relevant concepts of NSC like observer, environment, systems, perceiving, learning, etc. are to be introduced in a triadic semiotic-web which is observer- or operator dependent and entails the dyadic relationships of (W,O), (W,D) and (O,D) for each of the web-nodes.

Autology (AU) was introduced by Heinz von Foerster as the general domain of applying objects of all sorts onto themselves. Autological examples include

computation of computation, cybernetics of cybernetics, geometry of geometry, linguistics of linguistics, logic of logic, magic of magic, mathematics of mathematics, pattern of pattern, teaching of teaching (Kauffman, 2005:129)

The unity of operations (UO) is a holistic rule for second-order cybernetics research to study cognitive or senso-motoric operations like remembering, observing, inferring, moving, etc. not in isolation, but in combination or in their totality[6]. CR

[5] As a largely ignored corollary of the triadic configuration Heinz von Foerster is very explicit that also the scientific disciplines should be organized in accordance with triadic configurations. Again in "Computing in the Semantic Domain" von Foerster offers a sharp criticism of the ill-fragmented form of the disciplinary knowledge bases of his times. Referring, once again to triadic relationships which "have only recently been discovered" (*Ibid*:239), he goes on to assert that in normal science

> … it is only descriptions, D, of a single domains in isolation, the 'major disciplines', as 'physics' D(W), 'psychology' D (C), 'linguistics' D(D), and so on, to which the scientific community is accustomed to addressing itself, and for which powerful analytic formalisms have been developed. (v. Foerster, 1971:239)

[6] For cognitive processes, this heuristic rule has been formulated as the thesis of the unity of cognition. "If the mechanisms that are responsible for any of these (cognitive) faculties are to be discovered, then the

(composition rules) (v. Foerster, 2003:318ff.) or, to use another term by Heinz von Foerster, tessellations, as assembly-rules of non-trivial machines (v. Foerster, 2003:153pp.) for dimensionality 1 and 2, as compositions for dimensionality 3 and higher (v. Foerster, 2003:317pp.), as double closure of the sensory and the motoric system, etc. describe a set of dynamic rules or principles which become relevant for the emergence of complex configurations and ensembles.

In the configuration of Figures 2 and 3, NSC possesses a high impact potential for first-order level research across practically all academic disciplines and fields.

- First, Mode I of NSC [7] takes the products, outputs or more generally, the objects[8] of first-order research as its core research focus and transforms these objects into ensembles with a higher degree of robustness or resilience[9]. Mode I works with a group of second-order operators OP^{SO} which transform first-order objects Ob^{FO} into a new second-order form O^{SO} which can be characterized by a higher degree of robustness or,. alternatively, of resilience:[10]

$$OP^{SO}\ (Ob^{FO}) \rightarrow Ob^{SO}$$

These second-order objects can be transferred to the first-order level again and be implemented in the course of first-order research. Especially in the case of the social sciences and humanities these new NSC-objects should lead to significant changes in the final results and outputs.

Moreover, the normative side of Mode I provides also rules and rule systems RS^{FO} for reproducing past NSC-research in Mode I as well as for transforming first-order objects into configurations with higher levels of robustness or generality. Finally, another normative domain of Mode I offers rules and rules systems for reproducing completed Mode II-research and for improved or more efficient first-order research processes which are based on the neuro-cognitive studies of research processes themselves. Thus, Mode I can also be viewed as the design- or the rule mode of NSC which produces NSC-research designs or other relevant rules and principles for first-order research.

- Second, Mode II of NSC operates scientifically on scientific operations like measuring, writing, reading, classifying, inferring, designing, imaging, etc. which, by necessity, are used across all scientific fields, including NSC itself. Mode II relies on second order operators OP^{SO} which transform research processes

totality of cognitive processes must be considered."(v. Foerster, 2003:105)

7 For a reader not familiar with the expressions of Mode I and Mode II it is highly recommended to proceed to Müller, 2011 where these two modes are described in detail.

8 One can use entire scientific fields or academic disciplines as first-order objects and perform second-order analyses like studies on the cybernetics of cybernetics, the historiography of historiography, the sociology of sociology, economics of economics or linguistics of linguistics. Thus, the domain of first-order objects is considerably wider than the set of first-order outputs or products.

9 The two concepts of robustness and resilience will be used as equivalent. Both terms are attributes of first-or second order scientific objects of results processes and are based on a common measurement device which is capable to distinguish between low, medium and high levels of robustness or resilience.

10 On these second-order operators, see Müller, 2011, 2012 or 2013a.

or operations at the first-order level Op^{FO} into second-order research operations Op^{SO} which, due to their neural-cognitive organization and structure, are characterized by a relatively high degree of novelty.

$$OP^{SO}\ (Op^{FO}) \rightarrow Op^{SO}$$

What is missing at this point are some additional specifications with respect to different contexts in Mode I and in Mode II which become important for different clusters of second-order transformations.

4 The Cognitive Architecture of the New Science of Cybernetics: A Summary

For NSC as a second-order science in two self-reflexive modes two main differentiations for various contexts of analyses become relevant.

- The first distinction separates research processes in a context of discovery (*ex ante*) and a context of justification (*ex post*).
- The second division can be undertaken with respect to empirical and normative contexts.

These different contexts and the two NSC-modes can be recombined to eight main contexts for NSC research which, due to their morphological construction, comprise all possible second-order field of NSC. Turning to Mode I, the four main fields can be described in the following way.

- The empirical context of discovery (*ex ante*) for Mode I: In this domain second-order transformations are undertaken on first-order concepts, theories- or models in specific scientific domains or disciplines. In turn, these second-order concepts, theories or models can be used by researchers within specific academic disciplines or gields. For example, new second-order concepts for empirical research can be explored by social scientists in the new domain of second-order social research[11].
- The empirical context of justification (*ex post*) for Mode I: Here, the main emphasis lies on transformations of first-order objects as results of first-order level analyses. In general, the context of justification operates with final products, results or objects and transforms them to second-order objects with higher degrees of robustness. For example, several first-order psychological or medical tests can be analyzed at the second-order level and synthesized to a second-order test of tests with higher levels of robustness.
- The normative context of discovery (*ex ante*) for Mode I: This domain of NSC provides second-order versions of normative first-order elements. Here, the most important reconfiguration lies in the area of research designs which are transformed into second-order designs and which can be explored, subsequently, by researchers in different fields and disciplines. For example, new second-order concept formations for a particular science field can be used as core-components for a suitable second-order design for this special domain.
- The normative context of justification (*ex post*) for Mode I: To conclude the four contexts for Mode I, the fourth domain operates mainly on methodologies, rules and rule systems, etc. of first-order research

[11] For a transformation of second-order concepts on living conditions, inequality and quality of life, see Müller, 2013b.

and recombines them to second-order methodologies, rules, rule-systems, etc. Additionally, this specific context becomes relevant for the quality control of second-order research in Mode I by generating rules, methodologies and rule systems for Mode I of NSC.

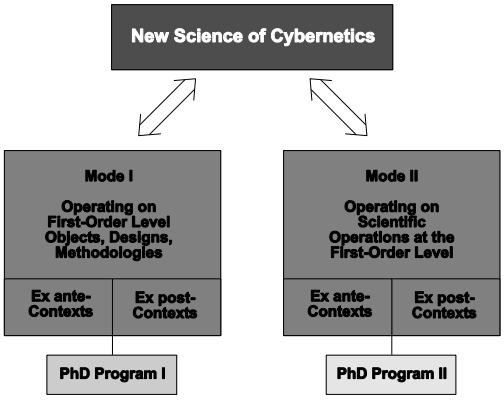
Shifting to Mode II, the four main domains can be characterized with the following core-features.

- The empirical context of discovery (*ex ante*) for Mode II: Here, second-order operational concepts like observing, measuring or testing are being developed and explored as second-order NSC-research as well.
- The empirical context of justification (*ex post*) for Mode II: In this domain, the results of the analysis of scientific operations at the first order level are investigated in a second-order context. Likewise, second-order objects can be analyzed in a second-order design in order to reach even higher levels of robustness.[12]
- The normative context of discovery (*ex ante*) for Mode II: This special context produces second-order designs for NSC-research in Mode II. Here, building blocks from first- or second-order research can be used and transformed into new second-order research designs for the analysis of operations of scientific operations.
- The normative context of justification (*ex post*) for Mode II: Finally, the fourth context generates rules and rule systems for second-order research in Mode II which are characterized by higher levels of robustness. This specific context acts as a vital domain for self-reflexive quality control for Mode II of NSC-research.

These eight different contexts for the two modes of NSC-research at the second-order level make it transparent that NSC acts as a catalyst for the creation of new second-order domains for academic fields and disciplines which, so far, were mostly focused on first-order levels exclusively. Thus, academic disciplines like sociology, psychology, biology and the like can and must build their corresponding second-order fields with the continuous help and support from NSC. In this sense, the second-order level becomes a densely populated regions of newly emerging second-order academic disciplines and fields on the one hand and NSC as the core-area of the second-order level on the other hand.

Figure 4 shows the fully developed organization of the new science of cybernetics in its two modes and its different contexts.

Figure 4 The Cognitive Organization of the New Science of Cybernetics

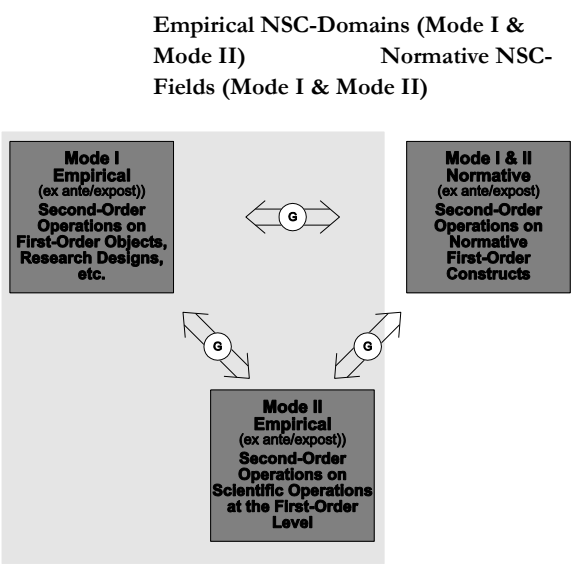


Moreover, Figure 5 points to a dense network of relations between the modes and

[12] As a terminological convention, analyses of second-order objects do not lead to a third-level analyses, but remain within the seond-order level, albeit with a higher level of generality.

contexts of NSC. In its fully developed form these eight different contexts across two NSC-modes produce each other in continuous cycle.

Figure 5 The Generative Relations between the Modes and Contexts of the New Science of Cybernetics



The final point in the specification of NSC is its potential for an academic program which can be implemented at universities of all sorts of variety.

5 The Institutionalization of the New Science of Cybernetics

NSC as it has been introduced until now is clearly suited to become an academic field with a set of curricula that correspond to its two different modes. Turning to such a curriculum context specifically, second-order cybernetics or, alternatively, NSC cannot or should not be organized for students in their entrance years to universities. It is almost impossible to conceive of NSC as an undergraduate or first level program in the Bologna process. Rather, NSC must or should build on disciplinary competencies which have been acquired in a special scientific field already. In an elementary sense second-order cybernetics cannot or should not be studied as an entrance discipline at the undergraduate level, but second-order cybernetics or the new science of cybernetics requires already a considerable experience in a particular field of inquiry. In terms of curricula NSC should be established only as special inter- and trans-disciplinary PhD-programs. More specifically, a PhD-program for NSC has a duration of three years (180 ECTS credits) and is located at the third level of the educational scheme according to the Bologna guidelines[13]. The NSC-program is divided into a cluster of courses (60 credits) and the individual work on a dissertation (120 credits).

In practical terms several faculties of a university must agree to create a special transdisciplinary program in NSC which is either focused on Mode I, on Mode II or on both modes.

The curricula of NSC for Modes I and II are rather different because they focus on different competencies.

- The curriculum for Mode I is oriented on second-order competencies of integration and meta-analyses for first-order level scientific objects and on the development and the transformation of research designs and of special and general methodologies. A Mode I-curriculum becomes especially relevant for highly standardized fields like medical, technical or psychological research, to name just a few larger scientific areas, as well as for studies on hybrid hot scientific

[13] The NSC-PhD-program both in Mode I and in Mode II can be constructed in a way which fulfils all the requirements and legislations in EU-member states and meets all criteria for doctoral study established by the European University Association (EUA). Consequently, it should be relatively easy to link the NSC PhD-program with already existing interdisciplinary PhD-programs and to establish international exchanges.

fields or for the orchestration of new forms oftrans-disciplinary research.
- For Mode II the curriculum places its main emphasis on second-order issues of embedded cognition and on second-order multi-level analyses of cognitive scientific processes. Thus, the program for Mode II follows more closely a special PhD-program in the neuro-cognitive sciences.

The curricula for Mode I and Mode II comprise the following lists of special second-order skills and competencies.

Mode I is centered on second-order competencies for carrying out different types of second-order investigations and studies for different clusters of first-order level objects and for re-designing first-order level research designs or methodologies.

- Second--order competencies in the areas of meta-mathematics, meta-logic and meta-statistics
- Second-order skills in the widening and deepening of theories, theory-groups, models and mechanisms, research programs and research traditions
- Second-order qualifications for the analyses of objects from first order level fields and disciplines in the area of measurements, data, tests, etc.
- Second-order qualifications for the investigations of objects from first order levels fields and disciplines and their societal contexts
- Second-order expertise for the analysis and transformation of first-order level research designs and for design development for first-order level disciplines and fields
- Second-order competencies in the study of research infrastructures
- PhD-oriented courses

For Mode II the following basic competencies and skills are to be acquired in the course of a three year program:

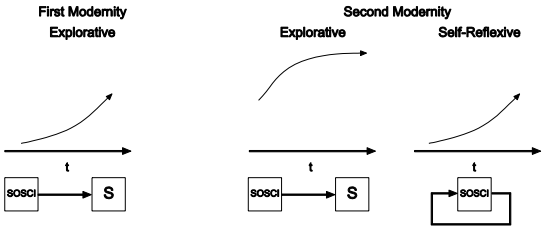
- Second-order competencies in the explanation of routines or practices in multi-level frameworks
- Second-order skills in the field of embedded cognition with respect to theory and data-integration
- Second-order qualifications for applying complex models and theory groups to special areas of scientific practices or operations
- Second-order qualifications for a theory-driven research project in the field of embedded scientific cognition
- Second-order competencies for an integration of complex cognitive technologies into research projects and designs in the field of embedded scientific cognition
- Second-order expertise for the creation of innovative research designs for the study of scientific practices
- Second-order competencies in the creation of suitable multi-level research infrastructures
- PhD-oriented courses

6 An Inversion in Novelty

In his impressive book on "risk-societies", Ulrich Beck (1986, 1997, 1998a, 1998b, 2000, 2002, 2007) points to a phase transition of the science system in general to a new stage which he qualifies as self-reflexive. Figure 6 captures some of the characteristic components of this transition. Within the old period of modernity or Modernity I science, organized as "little science", set out to explore the natural and social worlds with high returns of novelty. Within "big science" and Modernity II science – and especially, but not exclusively,

the social sciences - are more and more confronted with the effects of their own products, objects, technological designs, etc..

Figure 6 An Inversion of Novelty within the Contemporary and Future Science Landscapes



Vertical axis: Increases of novelty

One can add to Beck's assumption of a phase transition in science towards a self-reflexive configuration a second one which can be described as the inversion of novelty and which affects the sources of innovation. This inversion of novelty is represented by the right-hand part of Figure 6 which states that novelty especially in the social sciences is based to a diminishing extent on the exploration of new topics and domains, but on second-order analyses of already completed first-order level studies or objects. Evaluating, for example, a specific ensemble like a university, a national system of innovation, etc. for the tenth time will produce, in all probability, less innovative content than a second-order investigation of the nine evaluation reports so far.[14] Moreover, a rich variety of different second-order designs can be implemented, in principle, so that the outputs of second-order studies are capable of producing significantly higher degrees of novelty than first-level analyses.

As time goes by, the accumulation of more and more first-order level studies, articles or objects should strengthen and intensify the assumption of an inversion of novelty. This, in turn, implies that the creation of NSC as academic second-order field changes, in due course, from a curious desire of revitalizing an early vision by Heinz von Foerster to a neccessity for the contemporary or the future global science system as a whole.

7. Outlooks

Towards the end of this article, Table 2 summarizes the main differences between the old and the new science of cybernetics.

Table 2 The Differences between the Old and the New Science of Cybernetics

First-Order Cybernetics	New Science of Cybernetics
Transdisciplinary Field for Natural, Technical and Social Systems	Postdisciplinary Field for the Science System as a Whole
Steering, Controling of Technical, Natural or Societal Systems	Steering, Navigating, through Science Landscapes, Quality Control
Emphasis on Information and on Information Technologies	Emphasis on Knowledge, Knowledge Enhancement and Cyber-Technologies
Main Emphasis on Strong Forms of Control	Main Emphasis on Coordination and, thus, of Weak Forms of Control
Central for Control and Communication in Natural and Social Systems	Central for Communi-cation and Coordination for the Science and Research System
First-Order Level Research	Second-Order Level Research on First-Order Research(ers)
On Systems Observed	On Observing Systems
No Relevance for Self Reflexive Research	Central Relevance for Self-Reflexive Research
Observer Excluded from Research Designs	Observer Included in Research Designs

Following Table 2, the main differences between the old and the new science of cybernetics can be summarized in the subsequent points:

[14] For more details, see Müller, 2013c.

- First, NSC shifts its emphasis to knowledge, knowledge advancement and communication technologies rather than information, information science and information technologies, although these domains stay well within the reach of NSC as well. NSC becomes a self-reflexive field of science investigations[15] and can be described as the science of steering, control and communication for the science system itself, including NSC.

  Thus, NSC aims at strong ties with normal science research across all major scientific fields whereas the old science of cybernetics tried to establish strong ties between cybernetics and a variety of first-order fields like computer and information science, engineering, psychology, sociology, pedagogy and the like.

  NSC, especially in its Mode I, plays a weak control role through coordination and offers a variety of coordination impulses for the science landscapes like a basic orientation for emerging fields or potential focal points for first-order research and a strong quality control function by producing scientific objects of higher robustness. By contrast, the traditional science of cybernetics had its central focus on strong forms of control and control operations for natural, social or technical systems.
- Second, NSC operates on a new and distinctive level which has been categorized as second-order level and undertakes two self-reflexive re-entries, namely, first, a re-entry into the world of first-order level products, outputs or objects, including the domains of research designs or general rule-systems (Mode I), and second, a re-entry into the domains of scientific operations and their operators (Mode II). Thus, NSC opens up a new self-reflexive research field on research operations and their operators or, to use Humberto R. Maturana's or Heinz von Foerster's term, observers. NSC, especially in its Mode II, becomes the science of observers by observers for observers. In contrast, traditional cybernetics was restricted to various domains of systems observed.
- Third, NSC-designs are characterized by an additional self-reflexive element, namely by an explicit inclusion of researchers into research designs and into their research operations at the first-order or second-order level. Through this inclusion, NSC-research-operations become operationally closed in a strong sense and NSC, thus, operates within a closed configuration of researchers and their domain of investigations.

Four years after the initial publication of a new science of cybernetics and almost sixty years after the founding of the American Society for Cybernetics (ASC) the outlooks and the prospects of and for NSC have become brighter and more and more promising. What is needed most at this stage is a set of paradigmatic examples which demonstrate the usefulness and the cognitive utilities of NSC no longer *in vitro*, but *in vivo*.

[15] It should be stressed that this change is almost imminent or necessary, due to Heinz von Foerster's classification of first-order cybernetics as the science of systems observed and second-order cybernetics as the science of observing systems and, thus, as the science of observers.

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