Alfred Holl

Empiristic approaches to IS modeling

1 Motivation: the common features of natural sciences and IS – the essential empirical methods

– **observation**
– **modeling**
– **model formalization**
– **mathematization, reduction to axioms**

	natural sciences	IS
object of examination	object of cognition in the nature	information handling processes in organizations
manner of examination	observation	observation
utilization of the observation results	process of model construction	process of model construction
result of the process of model construction	formal model: formula	formal model: data model, information flow model, business process model
direct purpose	mathematical description	construction of system designs for IS
indirect use	explanation, understanding	optimization of information handling processes
transferability	prediction	reference models

The essential empirical knowledge-acquiring methods are a basis of comparison between IS and natural sciences.

Thus, IS can be considered as an empirical science, but has not yet reached the state of a natural science.

Therefore, epistemological approaches and results from natural sciences can successfully be transferred to IS.

2 Formal models 1

2.1 Formal models: features 1

Properties:
represented in formal language, i.e.:
semantically exact definition of terminology used

Examples:
- **maps, engineering drawings**
- **mathematical, physical and chemical formulae**
- **class models, business process models**
- **source code and object code of software**
- **notes in music**
- **phonetic transcriptions**

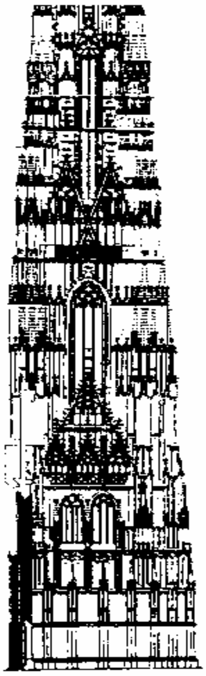
Some problems:
Accessibility to formalization depends
on the reality segment examined.
Only formal aspects of reality can be represented.

2 Formal models 2

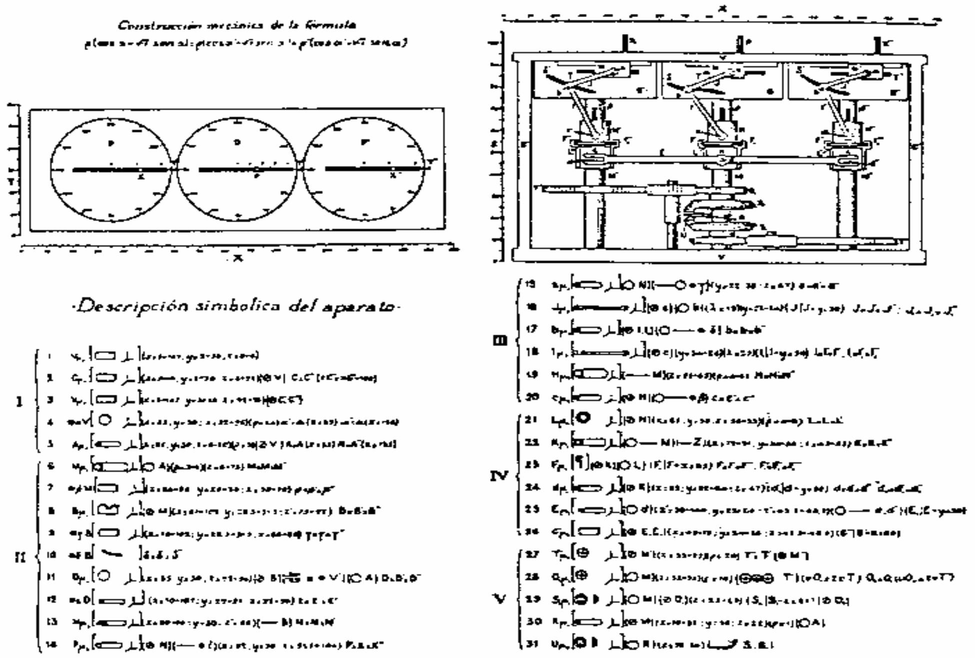
2.1 Formal models: features 2

Remark 1:
Mathematical-logical models with math.-logical correctness:
– logically complete (e.g. case structure)
including exceptions and constraints
entirely complete: impossible due to problem of isomorphy
– logically consistent (no contradictions)
– entirely explicit
Example: formula, e. g. free fall in the vacuum t = (2h/g)(1/2)**
IS: data structure diagram vs. ERM

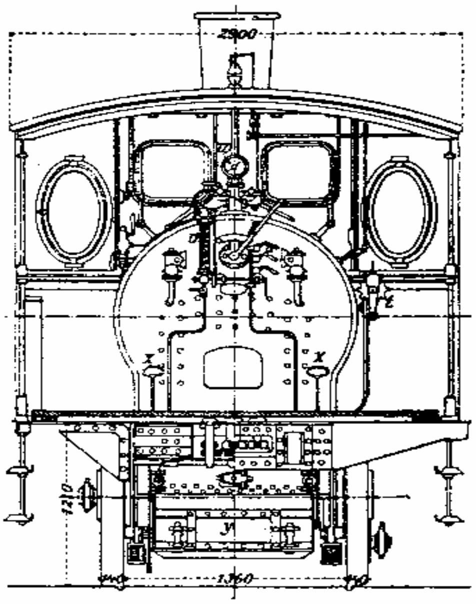
Remark 2:
Axiomatic models
– mathematical-logically simplest form
– absence of redundancy by reduction to axioms
Hilbert: Euclidean geometry of the plane (geometrical ideation)
Peano: natural numbers, counting
IS: 3NF model vs. data structure diagram



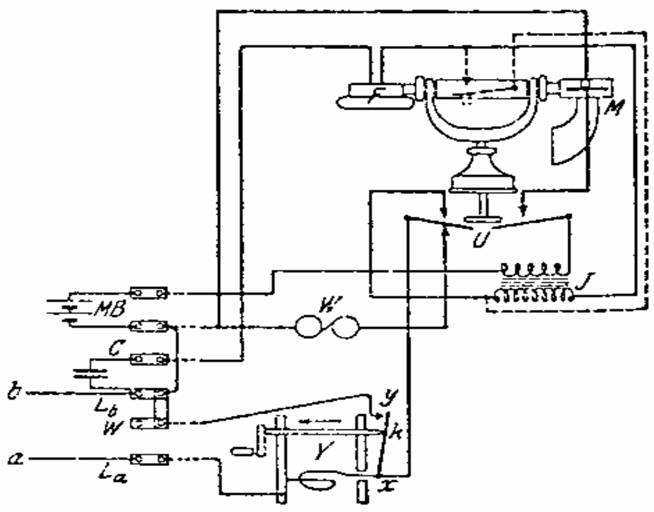
a) St. Stephan – Aufriß



c) Torres y Quevedo: Formale Sprache 1907 (aus [18])



b) Konstruktionszeichnung einer Lokomotive (aus Brockhaus' Konversations-Lexikon, 14. Aufl.)

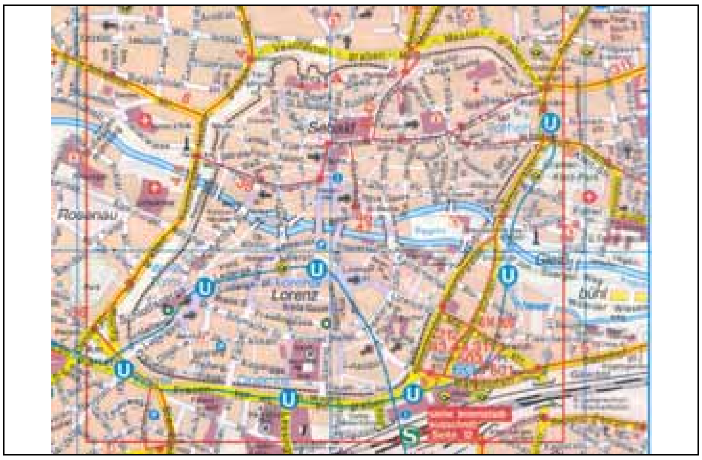


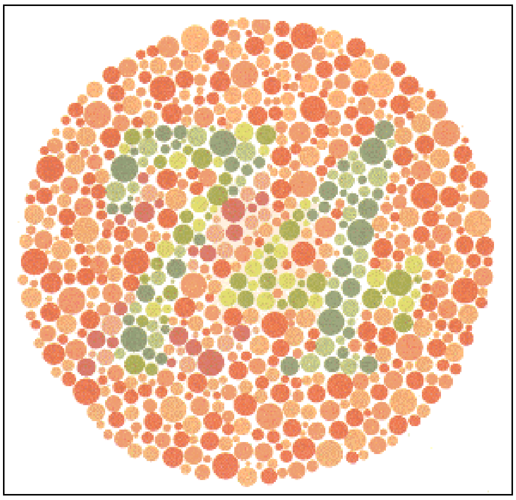
d) Telefon: Kombination Aufriß und Schaltung

Engineering drawings
(Zemanek, Geistiges Umfeld der IT, 1992, 136)

2 Formal models 4

2.2 Examples 2





Ishihara table

2 Formal models 5

2.3 Formal models in IS

**Computers are formal machines and, therefore,
don’t understand anything but formal languages.
Only formal aspects of reality are accessible to computers
via formal models.**

**“The range of interpretation must be reduced to zero
as soon as the handling of concepts
is transferred to machines
which only know logics,
but do not know any hermeneutics, any method of understanding.**

**„Sobald aber diese Tätigkeit [das Operieren mit Begriffen]
auf Maschinen übertragen wird,
die nur Logik,
aber keine Hermeneutik, keine Methode des Verstehens kennen,
ist der Interpretationsspielraum auf Null zu bringen.“**

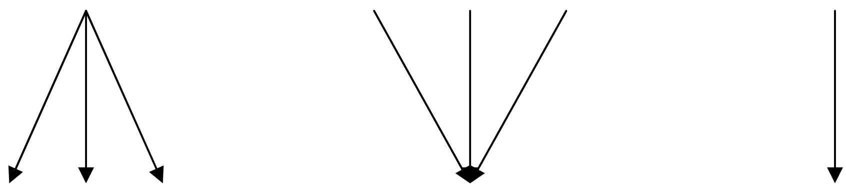
H. Wedekind,
Was heißt und zu welchem Ende studiert man Betriebsinformatik, ZfB 50(1980), 1269

**“We should recognize that already now
programming is much more than an intellectual challenge;
the art of programming is the art of organizing complexity,
of mastering multitude and
avoiding its bastard chaos as effectively as possible.”**
E. W. Dijkstra: Structured Programming
from Knowles, Larmouth, Kneightson: Standards for OSI. p. 20

2 Formal models 6

2.4 Natural and formal languages: (non-)ambiguous communication

natural language		formal language
one meaning	many meanings	one meaning



many forms	one form	one form
synonymy (can occur in SQL)	homonymy polysemy	non-ambiguity

quasi-synonymy, quasi-homonymy: overlapping meanings

Features of formal languages:

– standardization of word semantics (meanings)
– diachronous stability of word semantics
– standardization of phrase semantics:
  e.g. SPO only for propositions, not for questions
  sequence of parts of a sentence determines semantics

3 Cognitive processes in empirical sciences: the construction of descriptive models 1

3.1 Induction, deduction 1

Induction: specific to general
(infinite quantity of theories)

A model is inductively (→ analogy!) constructed / modified on the basis of (interpreted / classified) observation data by a creative or intuitive act, inspiration, idea, flash of genius. Abstraction and simplification are required as well.

The induction question is always:
From which more general statement could the original observation results be deduced?

Deduction: general to specific
(one single result)

Deductively, predictions are derived from the model.
Experiments for their test
(and therefore the model's test and modification:
verification or falsification)
are designed.

From an induction result (a scientific model), however, not only the original observation data (the starting point of the model) can be deduced, but also further statements (predictions).
The latter permit a test of the model by means of selected observations (cf. correspondence theory of truth).

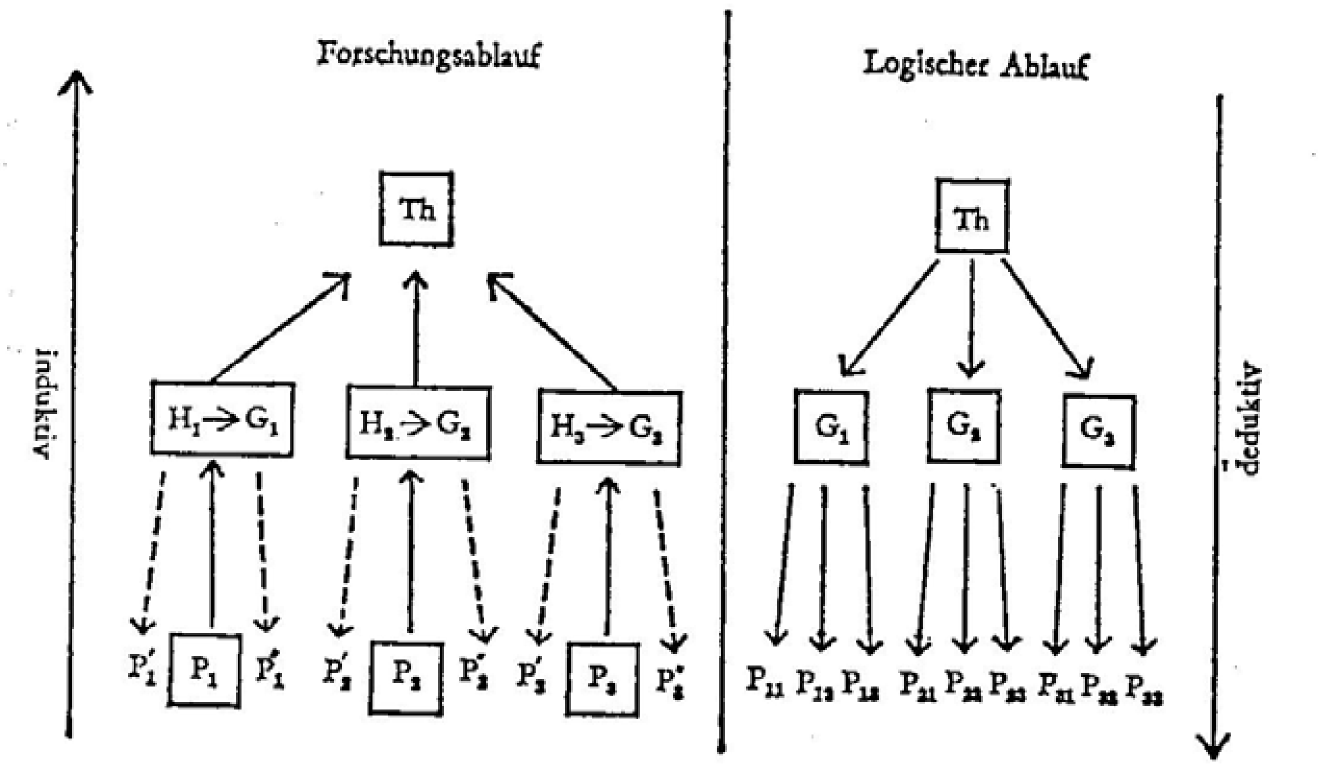
3 Cognitive processes in empirical sciences 2

3.1 Induction, deduction 2

These considerations are the basis for Karl Popper's fallibilism: A model is derived from comparatively few observations.

By extension of its domain (mathematically spoken), the model can be applied to particular situations which did not serve as its starting point.

Therefore, it is a principle that you can never exclude the occurrence of a particular observation which might falsify (disprove) the model via modus tollens (→ analogy).



Die Abkürzungen bedeuten: Th = Theorie, G = Gesetz, H = Hypothese, P = Protokollaussage.

(Seiffert, Wissenschaftstheorie 1, 1991, 167)

3 Cognitive processes in empirical sciences 3

3.1 Induction, deduction 3

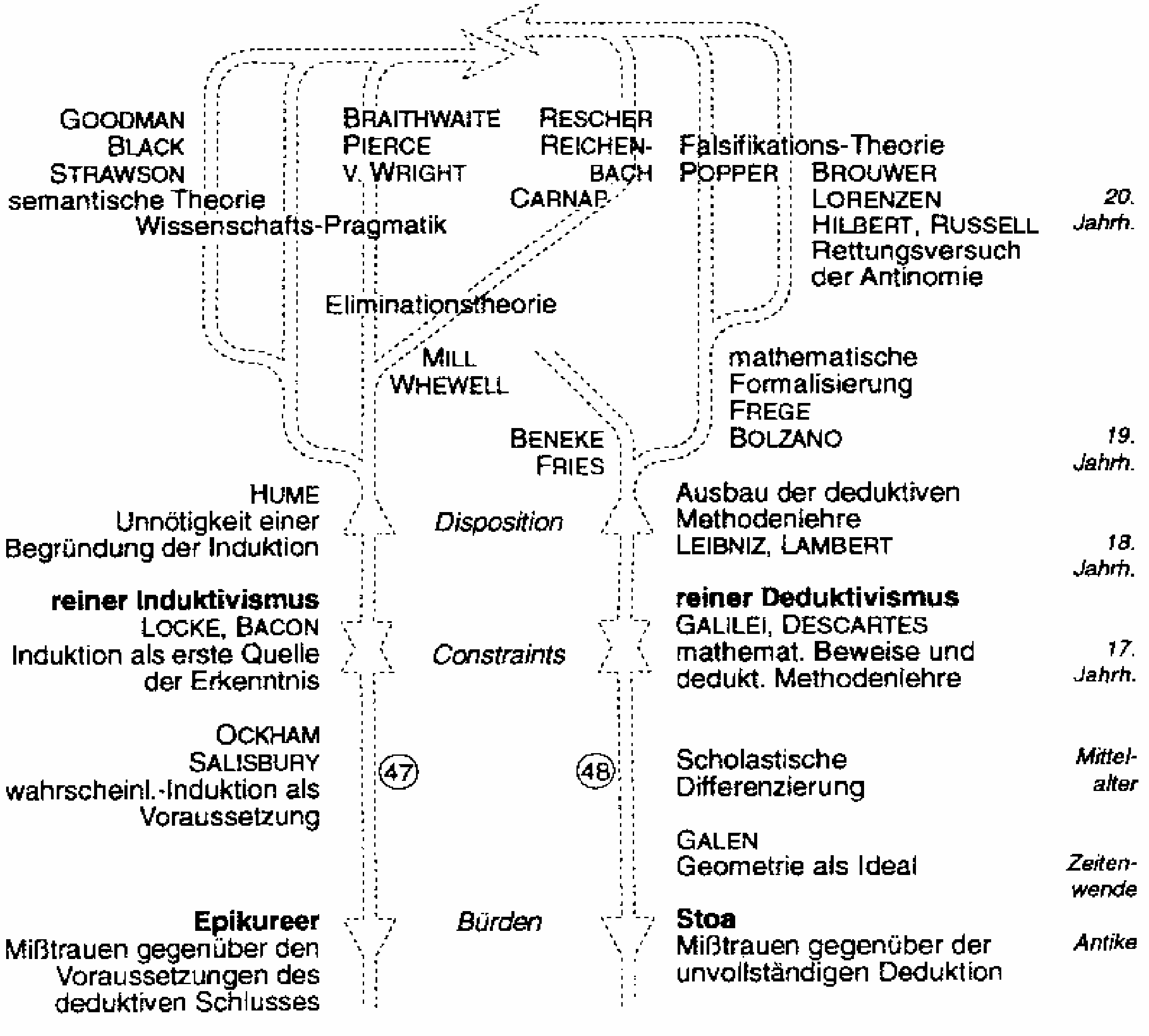


Abb. 47/48: *BCD-Serien zum Induktions-Deduktionsproblem.* Die Bürden eines Mißtrauens entweder gegenüber den Voraussetzungen des logischen Schließens oder aber gegenüber der unvollständigen Induktion führt zu den Constraints des reinen Induktivismus oder aber Deduktivismus, mit den Dispositionen zu den Rechtfertigungs-Theorien (oder aber Rettungs-Theorien).

Inductivism and deductivism
(Riedl, Mit dem Kopf durch die Wand, 1994, 233)

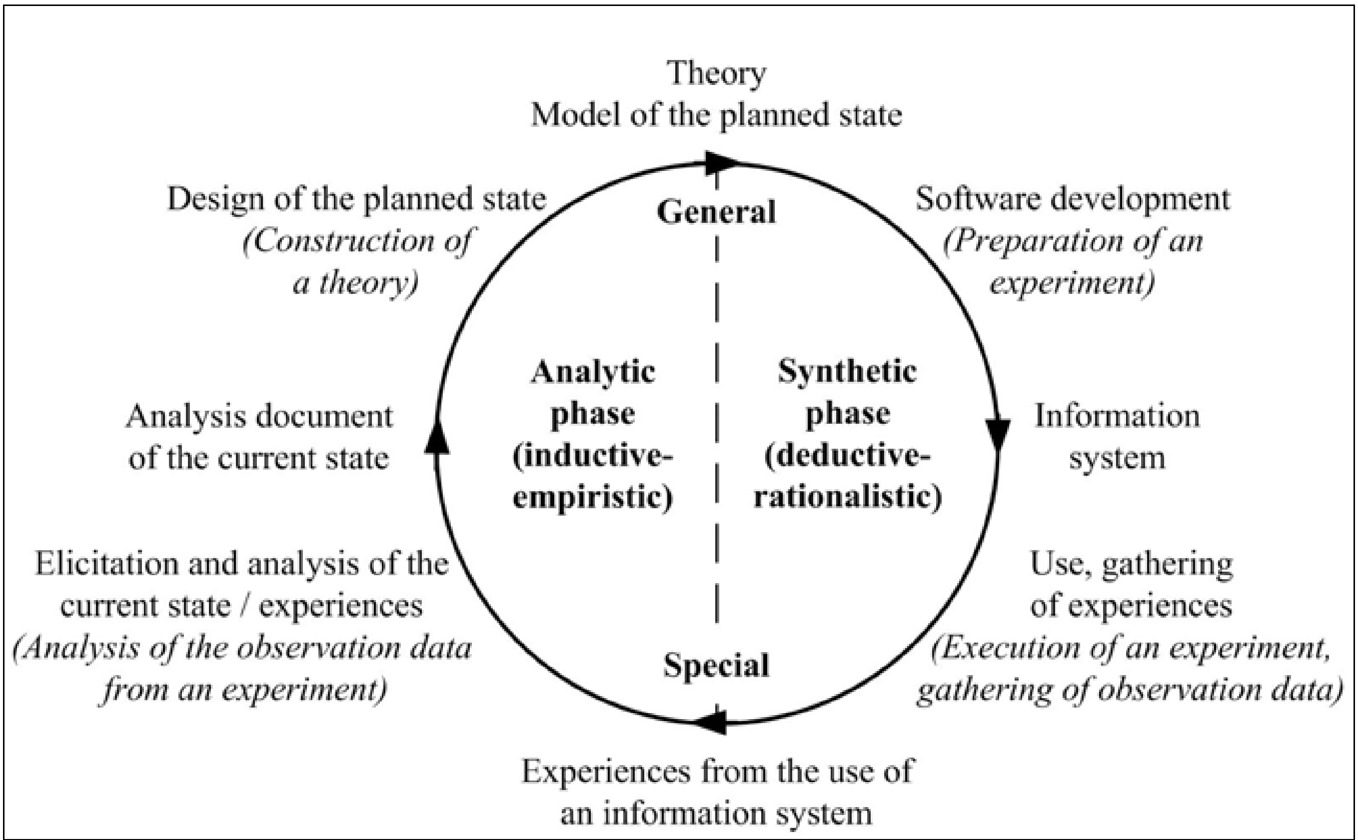
3 Cognitive processes in empirical sciences 4

3.2 Mayeutic cycle 1

Model construction (induction) and model test (deduction) are joined to and executed iteratively in a circular process.

It is called the mayeutic cycle,
in our days also experimental learning model (ELM)

Ancient Greek *μαιευτική τέχνη* 'midwifery'
Socrates' technique to "extract" knowledge
from "officially" uneducated people.



Mayeutic cycle in IS and natural sciences
(Holl / Paetzold / Breun 2011, p. 24,
according to Holl, 1999, p. 175)

3 Cognitive processes in empirical sciences 5

3.2 Mayeutic cycle 2

1. Analytic phase: inductive-empiristic

1.1 Observation data is interpreted / evaluated / classified.
- **PLM (product life-cycle management): analysis of a problem**
- **IS: elicitation and analysis of the current state**

1.2 A model / theory is inductively constructed / modified
by a creative or intuitive act, inspiration, idea, flash of genius (→ analogy!).
- **PLM: design of a product**
- **IS: design of the planned state (lock and key)**

2. Synthetic phase: deductive-rationalistic

2.1 Deductively, predictions are derived from the model.
Experiments for their test (verification or falsification; and therefore the model's test) are designed and prepared.
- **PLM: production of a product**
- **IS: software development (IT design, programming, test)**

2.2 The experiments and measurements are executed, observation data is gathered.
- **PLM: the product is used**
- **IS: the technical information system is used in an organization**

back to 1.1 The new observation data is interpreted, compared with the predictions, evaluated and classified.

Empiristic-inductive parts: perception is the measure for truth
Rationalistic-deductive parts: mind is the measure for truth

3 Cognitive processes in empirical sciences 6

3.2 Mayeutic cycle 3

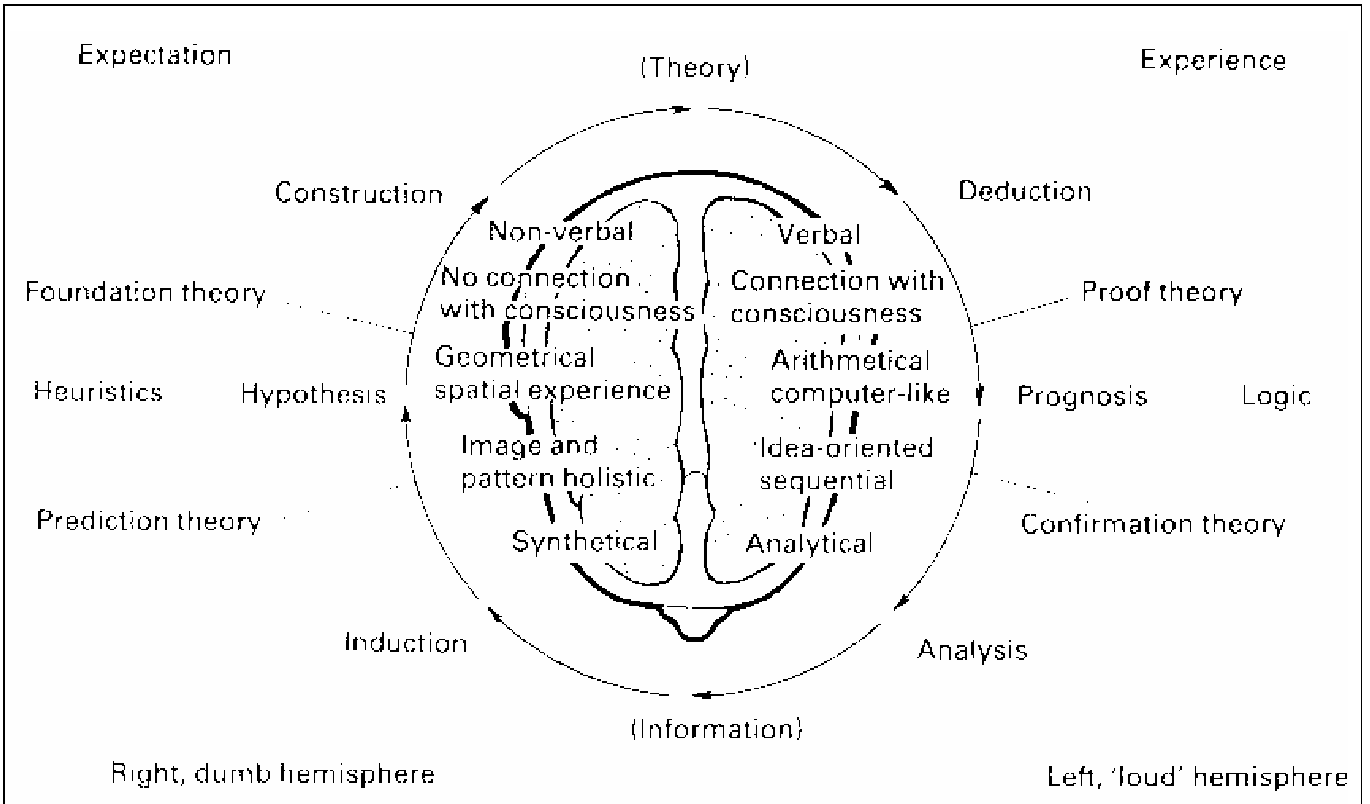


FIG. 60 The parallelism of hemispheric and cognitive functions of the human brain. The complementary functions of our brain hemispheres are inserted according to the experiences of neuropsychology (after Levi-Agresti and Sperry, 1968; from Eccles, 1975), the complementary performances of the cognitive process according to the experiences with the dynamic of scientific theory formation (Oeser, 1976 and the results of our own evolutionary investigations). Note this extensive agreement (compare, in addition, Figs 59, 58 and 29).

Rupert Riedl's symmetric octogonal interpretation:
mayeutic cycle and brain hemispheres
(Riedl, R.: Biology of knowledge. 1984, 186)

3 Cognitive processes in empirical sciences 7

3.2 Mayeutic cycle 4

Riedl visualizes the knowledge gain
from the multiple iteration of the mayeutic cycle
with an upwards widening helix:

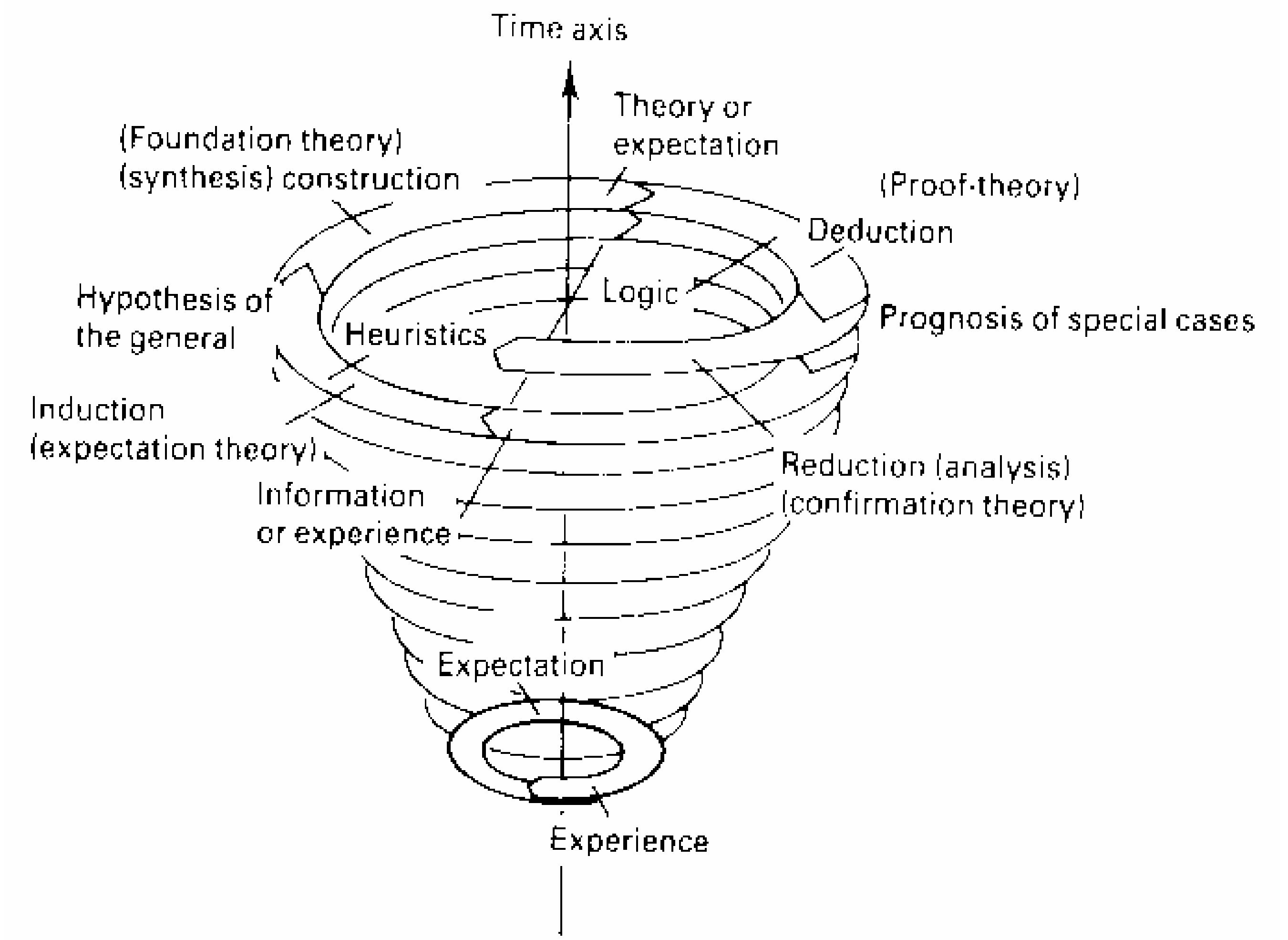
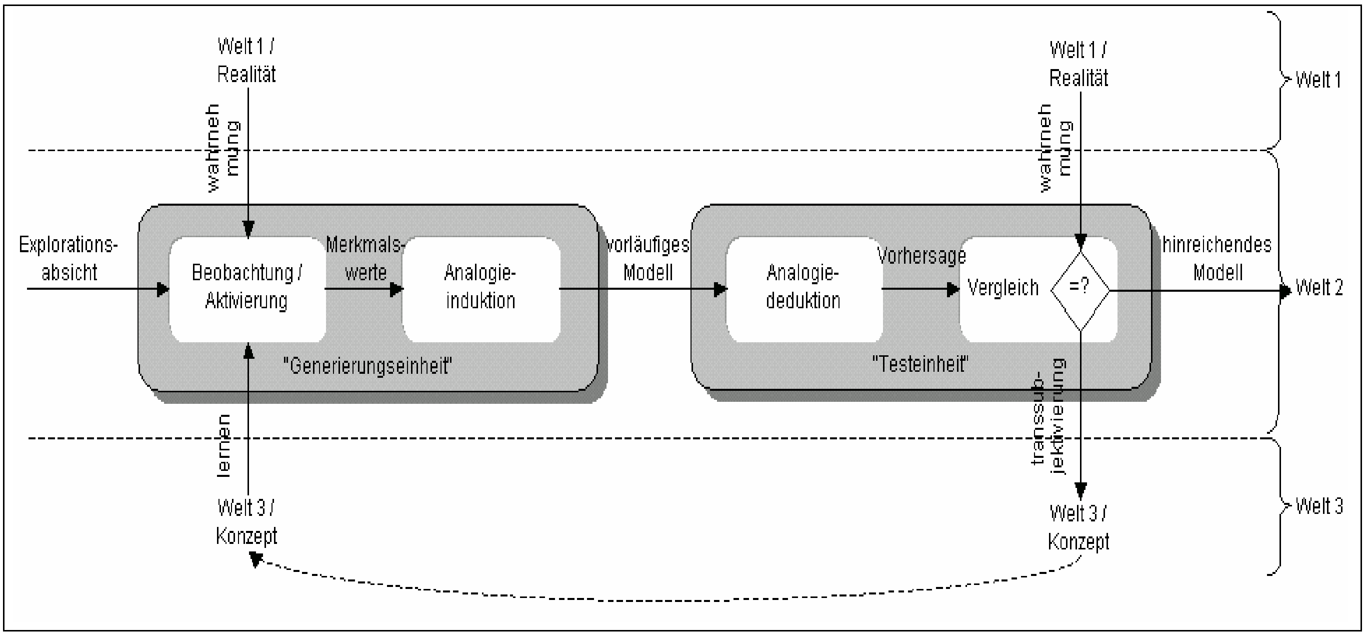


FIG. 29 The cycle of cognitive gain, hence the growth of knowledge and certainty according to Erhard Oeser's theoretical system-functional model of the dynamics of theories. The symmetries contained in this algorithm correspond to those which were found prepared in the phylogeny of biological cognitive processes. It is only that they are more differentiated at the level of epistemology (from Oeser, 1976; extended into biological history).

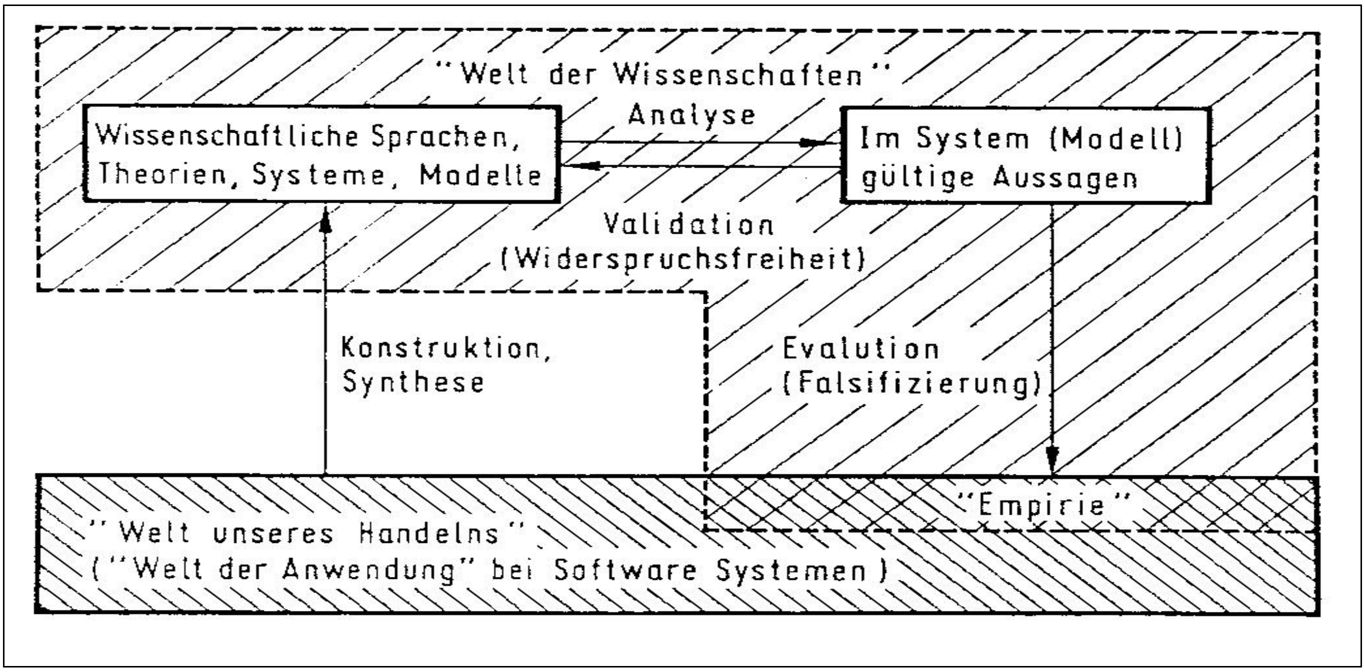
(Riedl, R.: Biology of knowledge. 1984, 169)

3 Cognitive processes in empirical sciences 8

3.2 Mayeutic cycle 5



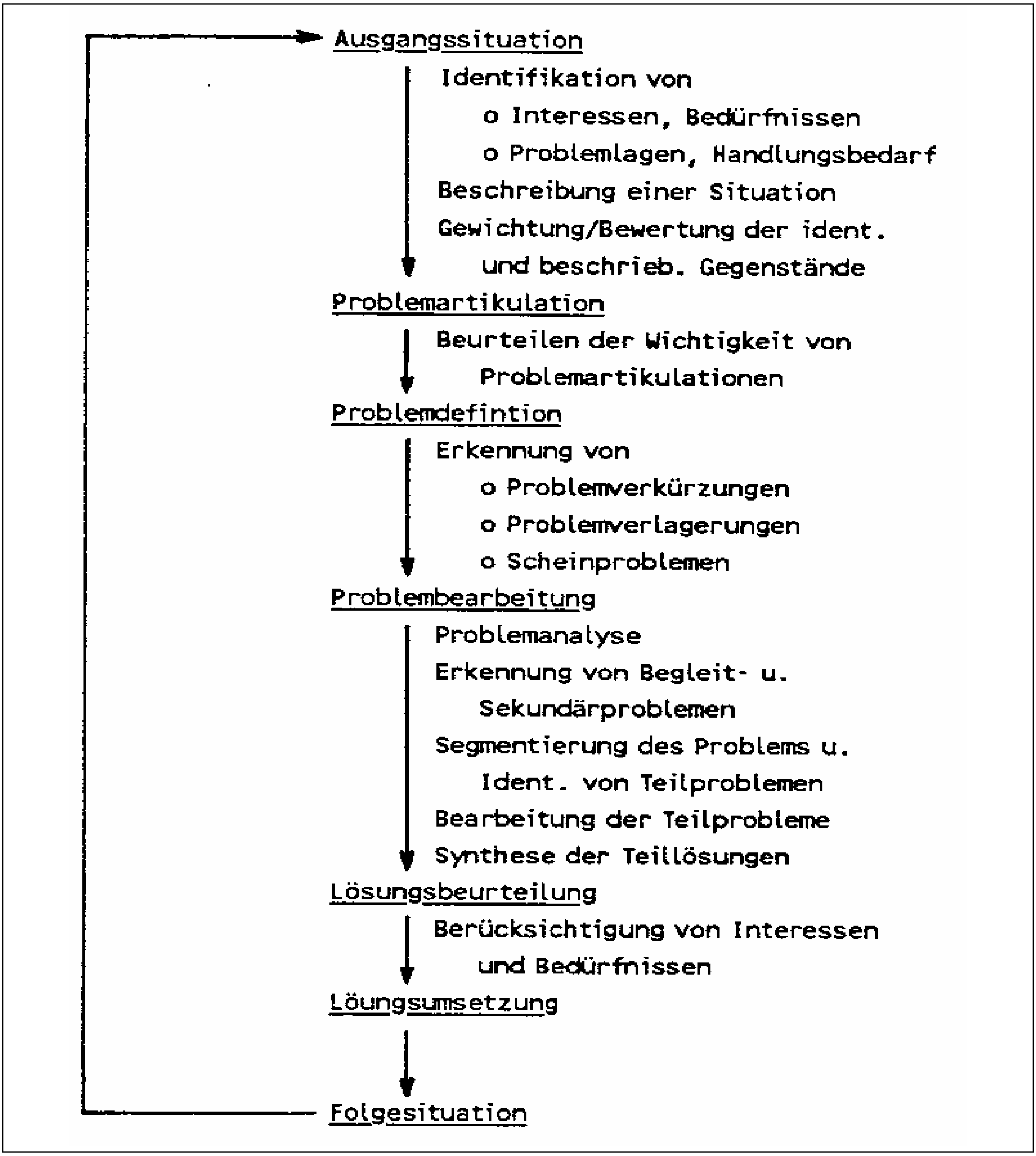
Induction, deduction, mayeutic cycle, Popper's three worlds (Holl / Auerochs, Analogisches Denken, 2004, 384)



World of activities and world of science in a mayeutic cycle (Luft, Rationaler Sprachgebrauch, *, 213)**

3 Cognitive processes in empirical sciences 9

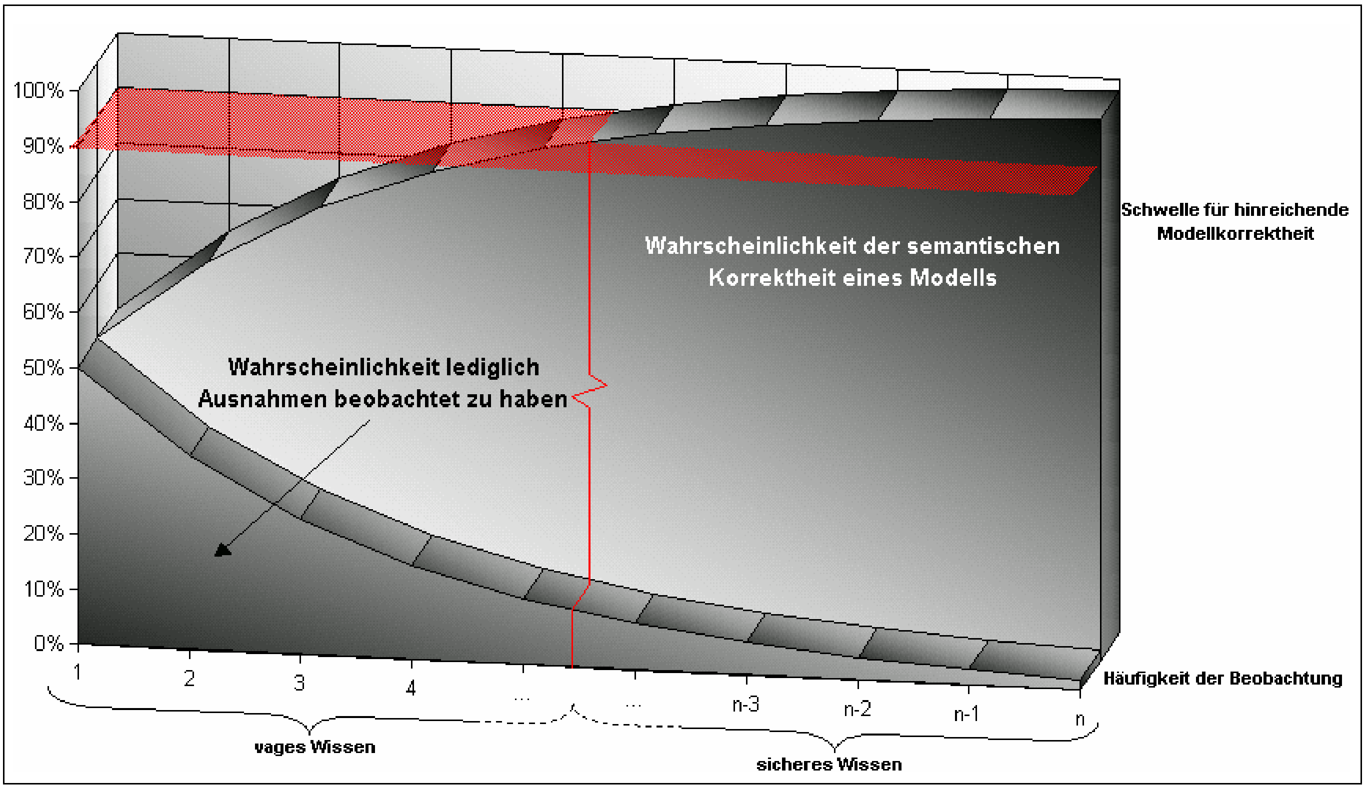
3.2 Mayeutic cycle 6



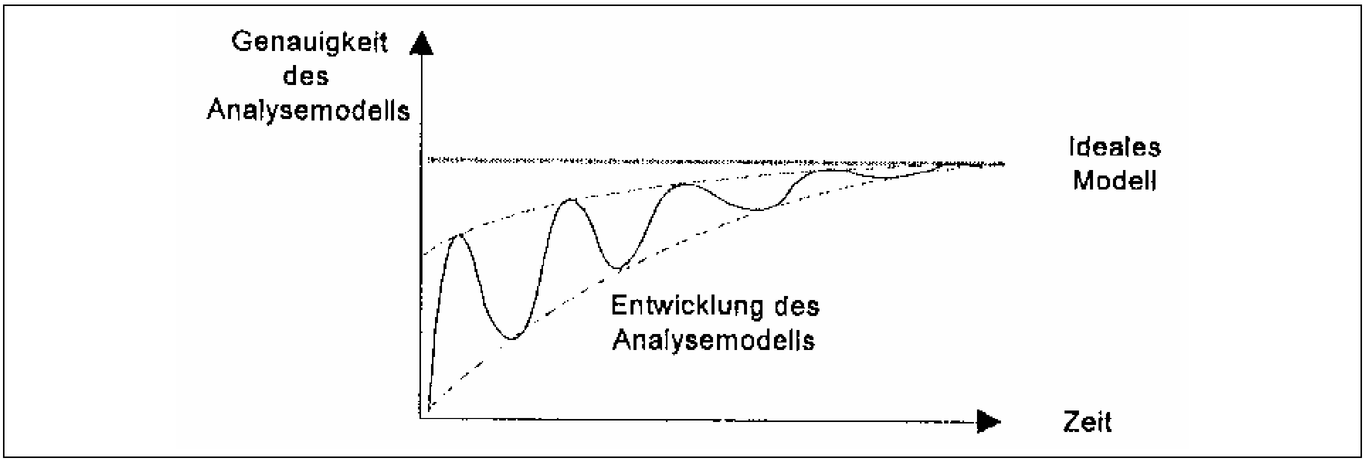
The problem solution process as a mayeutic cycle
(Luft, Informatik als Technikwissenschaft, *, 242)**

3 Cognitive processes in empirical sciences 10

3.2 Mayeutic cycle 7



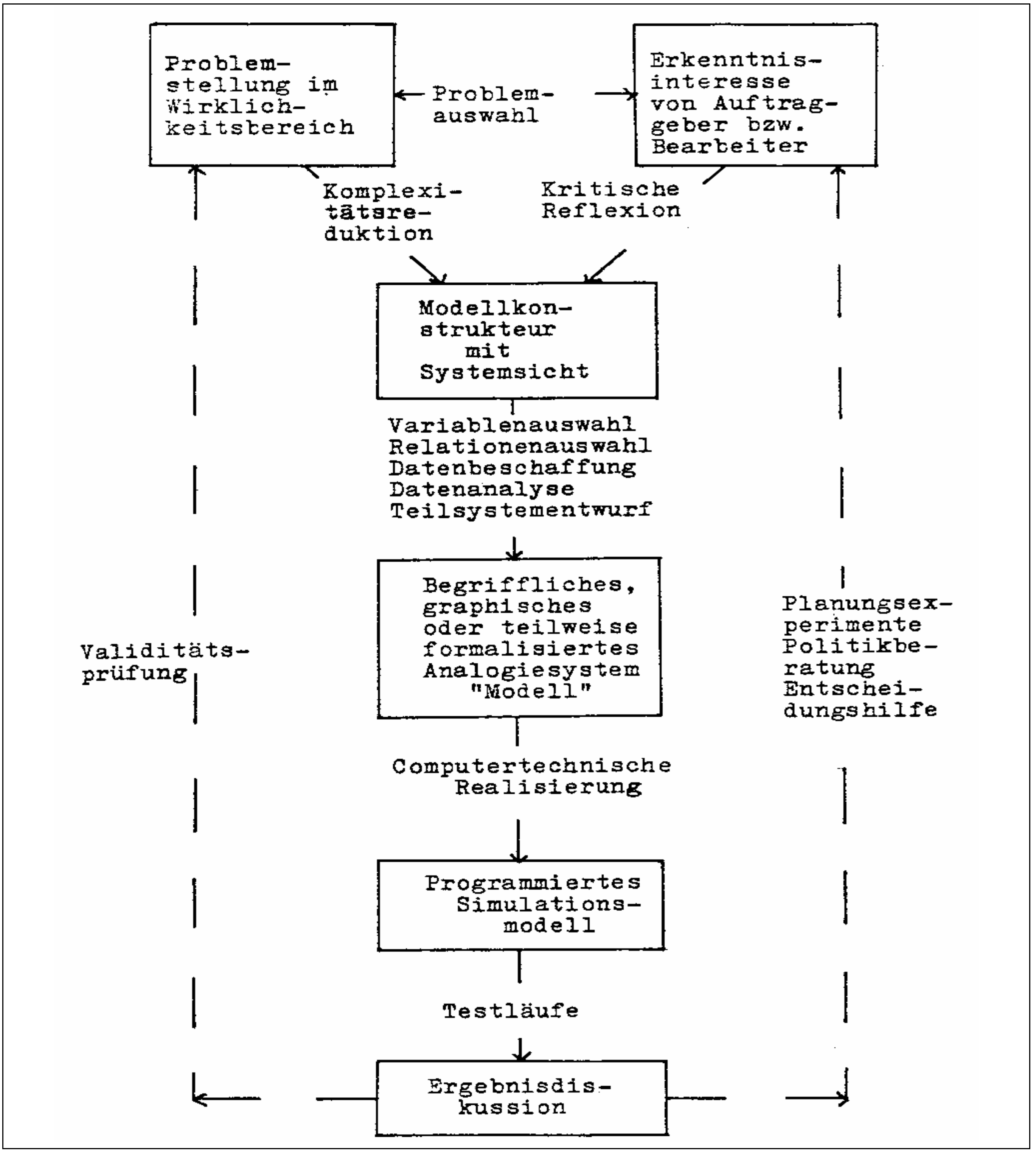
The probability for the correctness of a model increases with the number of observations / iterations. (Holl / Auerochs, Analogisches Denken, 2004, 384)



Asymptotic approximation of a model (Holl / Scholz, OO und Popper, 1999)

3 Cognitive processes in empirical sciences 11

3.3 Mayeutic cycles in IS 1

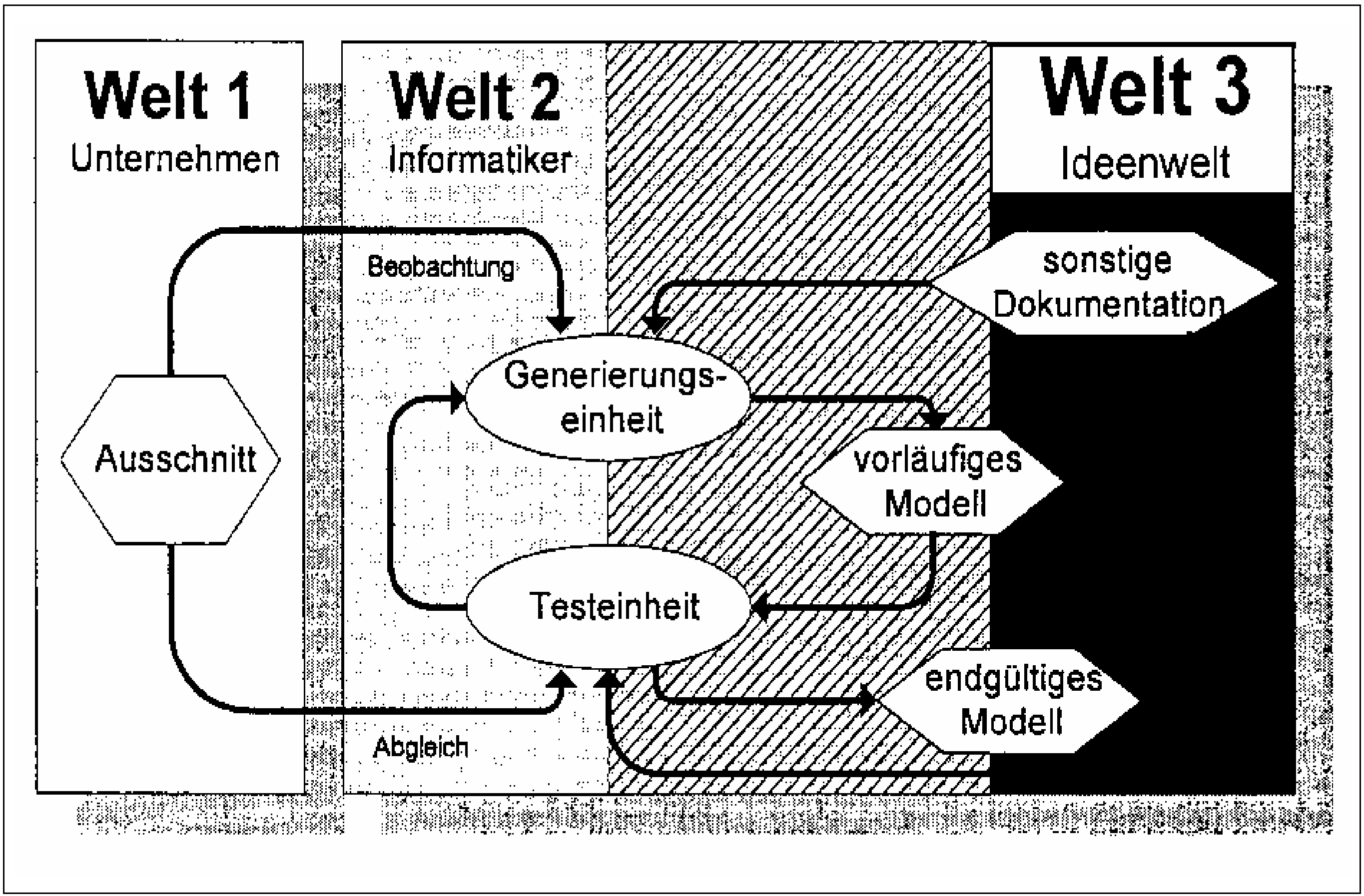


Model design in a mayeutic cycle
(Kulla, Angewandte Systemwissenschaft, 1979, 171)

3 Cognitive processes in empirical sciences 12

3.3 Mayeutic cycles in IS 2

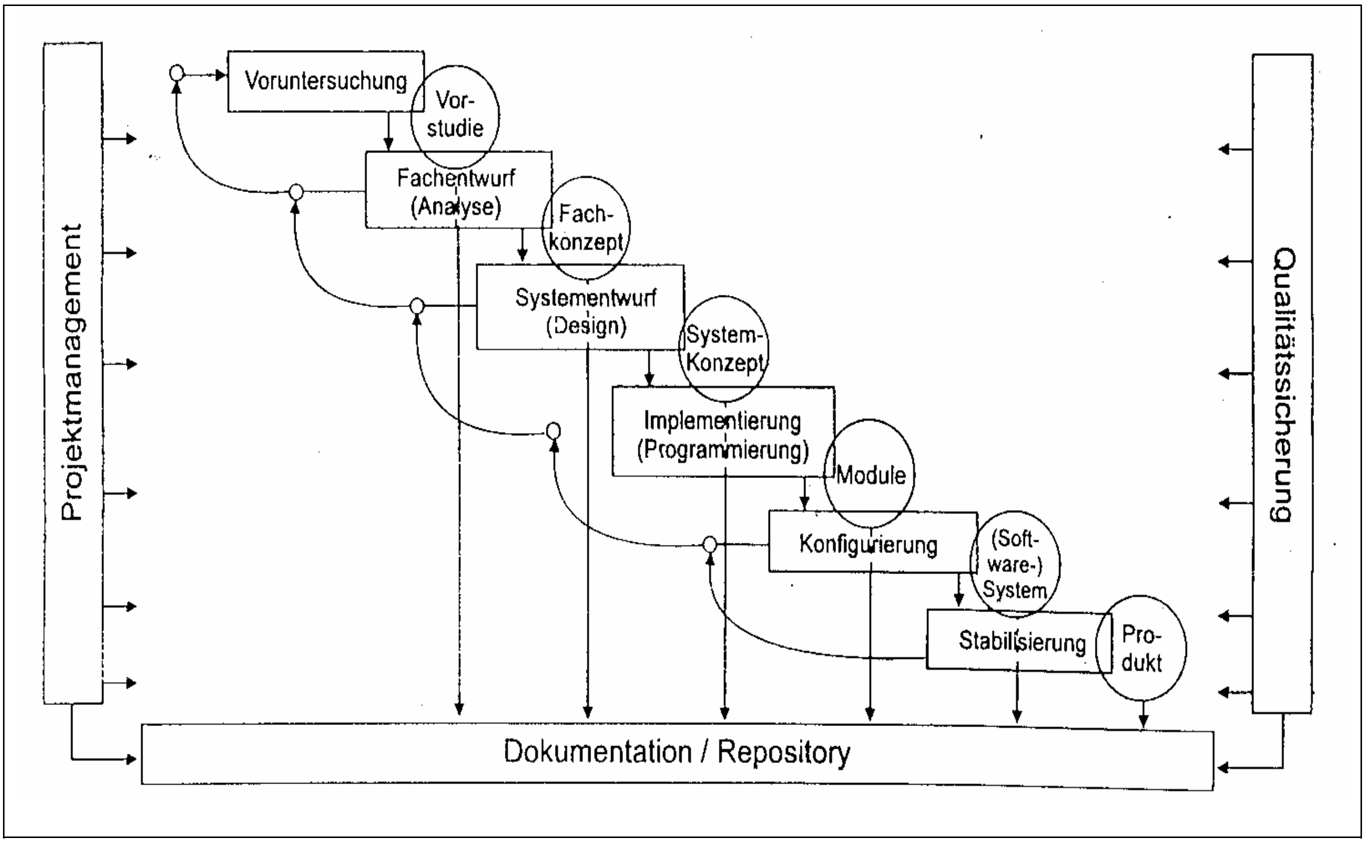
Analytic phase of a software life cycle
~ inductive half of a mayeutic cycle
Synthetic phase of a software life cycle
~ deductive half of a mayeutic cycle



Model design and Popper's three worlds in a mayeutic cycle
(Holl / Scholz, OO und Popper, 1999)

3 Cognitive processes in empirical sciences 13

3.3 Mayeutic cycles in IS 3



Nested mayeutic cycles
SW development model of DATEV e.G., Nuremberg, Germany

4 Particularities of cognitive processes in IS 1

We already know practical structured cognitive processes in IS: phase concepts, software life cycle models.

Natural sciences which describe existing situations
are completed by technology which prescribes future situations.

IS comprises both of the two aspects:
elicitations of current states and
designs of planned states.

→ action research, design theory

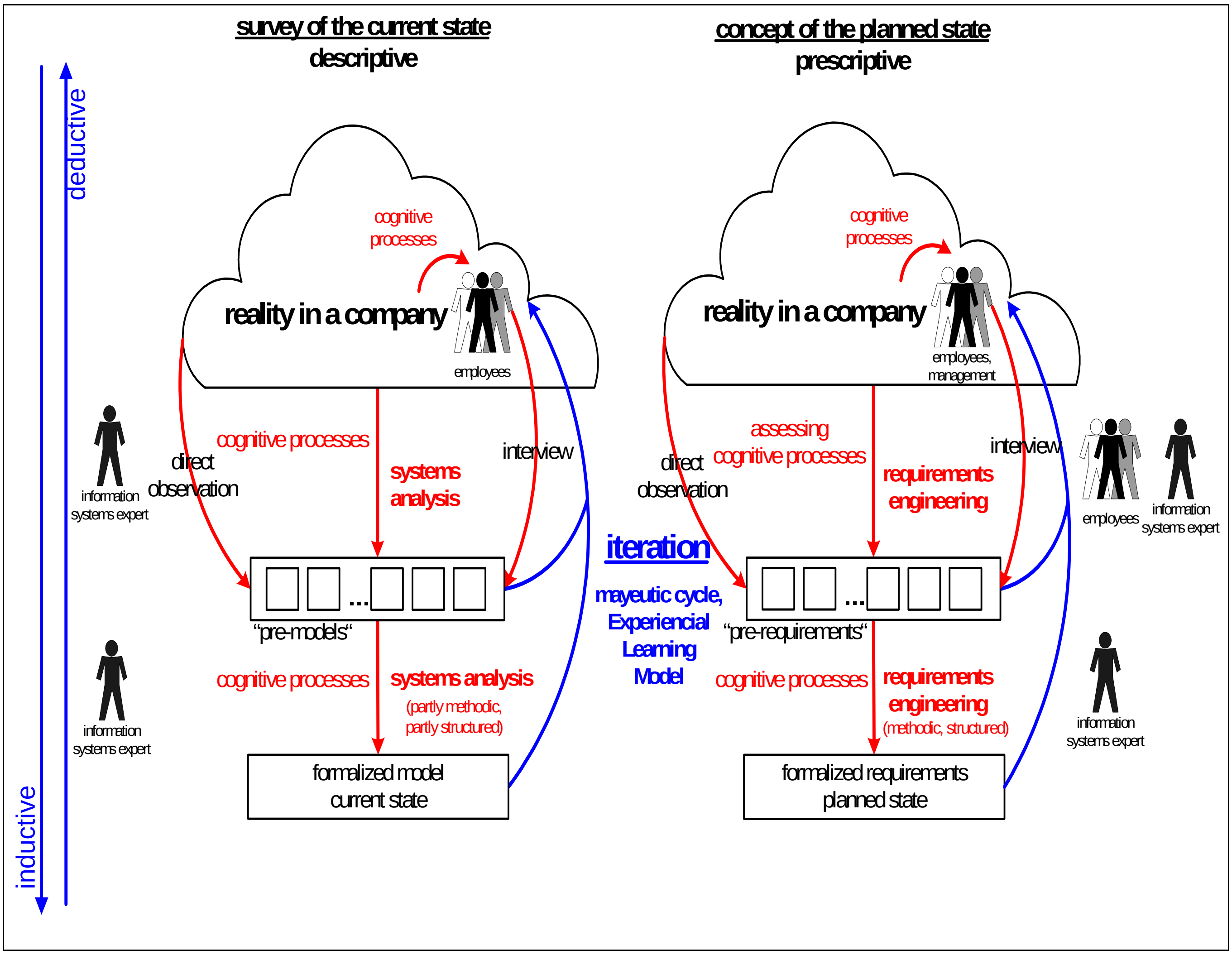
Compared with objects of cognition in natural sciences,
the most important difference of objects of cognition in IS is that they (that is the employees) can talk in a natural language.

The IS experts can invite the employees for interviews and workshops
The employees, however, are not trained in a formal language so that their utterances have the form and value of
pre-models (pre-stage of a model) and
pre-requirements (pre-stage of a requirement).

The utterances of the employees have to be checked for their mathematical usability (well-definedness).

Therefore, there are mayeutic cycles
on the descriptive side as well as on the prescriptive side.

4 Particularities of cognitive processes in IS 2



Cognitive processes in IS modeling
(Holl / Maydt: Epistemological foundations of RE, 2007, 53)

The process of designing IS models is a lot more complex than demonstrated up until now.
E.g., there are different design techniques, such as top-down, inside out, view integration, umbrella models.
See advanced courses on IS.

4 Particularities of cognitive processes in IS 3

In IS practice, the foundations of both of the two mayeutic cycles can be more or less well based upon epistemological reflections:

level	partly methodic, partly structured	epistemology-based	epistemological foundation
eliciting the current state	systems analysis	(missing)	systems theory
designing the planned state	business concept modeling	requirements engineering	linguistics, psychology, …

Partly methodic and structured vs. epistemology-based cognitive methods of information systems (Holl / Maydt: Epistemological foundations of RE, 2007, 54)

5 Two sources for model construction in IS 1

Besides the empiric way of model construction in IS (1 below), there is a rationalistic way (2 below) as well.

Popper's World 1 (reality): empiristic method/approach
organization, enterprise, department
  observation and interviews (W3)
    of employees by a model designer
    (contrary to natural sciences: only observation)
  preliminary description in pre-formal models: natural language
  abstraction
  check whether terminology is mathematically well-defined
  final type construction
  formalization (degree of pre-formalization is different)
  reduction to axioms

often used for peripheral areas of models
often used for individual parts of an organization
(nominalist point of view: enumeration of individual objects)

Popper's World 3 (models, concepts, ideas): rationalistic method
reference models
  activation in a model designer's brain
  analogy-based transfer

often used for central areas of models
often used for standard parts of an organization, e.g. accounting
(universalist point of view: search for general principles)

Final step: integration of individual and reference models.

5 Two sources for model construction in IS 2

external world ↓ World 1 objects of cognition	phenomenon, individual experience ↓ World 2 knowledge of an individual subject of cognition			model, theory ↓ World 3 common knowledge
	perception, cognitive processes (empiristic) ↓ reconstruct. of World 1 →	memory	learning rationalistic ↓ activations of World 3 ←	
←	design, influence ←	↓ creation, induction ↓ new ideas, knowledge	→ publi-cation	→

Bi/trilateral semiotic sign		
materialized signifiant, vox	code of interpretation	signifié, conceptus W2|W3
object of cog.		

Model as complex bi/trilateral semiotic sign		
materialized model repre sentation	code of interpretation	model meaning W2|W3
object of cog.		

6 Empirism – Rationalism 1

The discussion about the background of the two sources for model construction in IS is quite old.

Historically, there are two different critieria for settling the truth of statements:
– naive empirism: experience and induction
– naive rationalism: reason and deduction

Both of the two views cannot survive in isolation, they have to be integrated.

Even the mayeutic cycle – at first sight merely empiristic – contains empiristic and rationalistic parts, that is, observations and theories mutually influence each other:
– Observations (experiences) change observation frameworks.
– Observation frameworks (intellect) exert an influence on the selection of observation objects and on observation interpretations.

6 Empirism – Rationalism 2

Empirism	Rationalism
nominalism (enumeration of individual objects)	universalism (search for general principles)
natural sciences	humanities
perception	thinking, reasoning
body	mind
induction	deduction
Popper's World 1	Popper's World 3
Aristotle (384-322)	Socrates (470-399) Platon (427-347) René Descartes (1596-1650 Sth)
John Locke (1632-1704) David Hume (1711-1776) John Stuart Mill (1806-1873)	Baruch Spinoza (1632-1677) G. W. Leibniz (1646-1716)
Immanuel Kant (1724-1804): – synthesis of empirism and rationalism, – transcendental epistemology Konrad Lorenz (1903-1989): – evolutionary epistemology	

6 Empirism – Rationalism 3

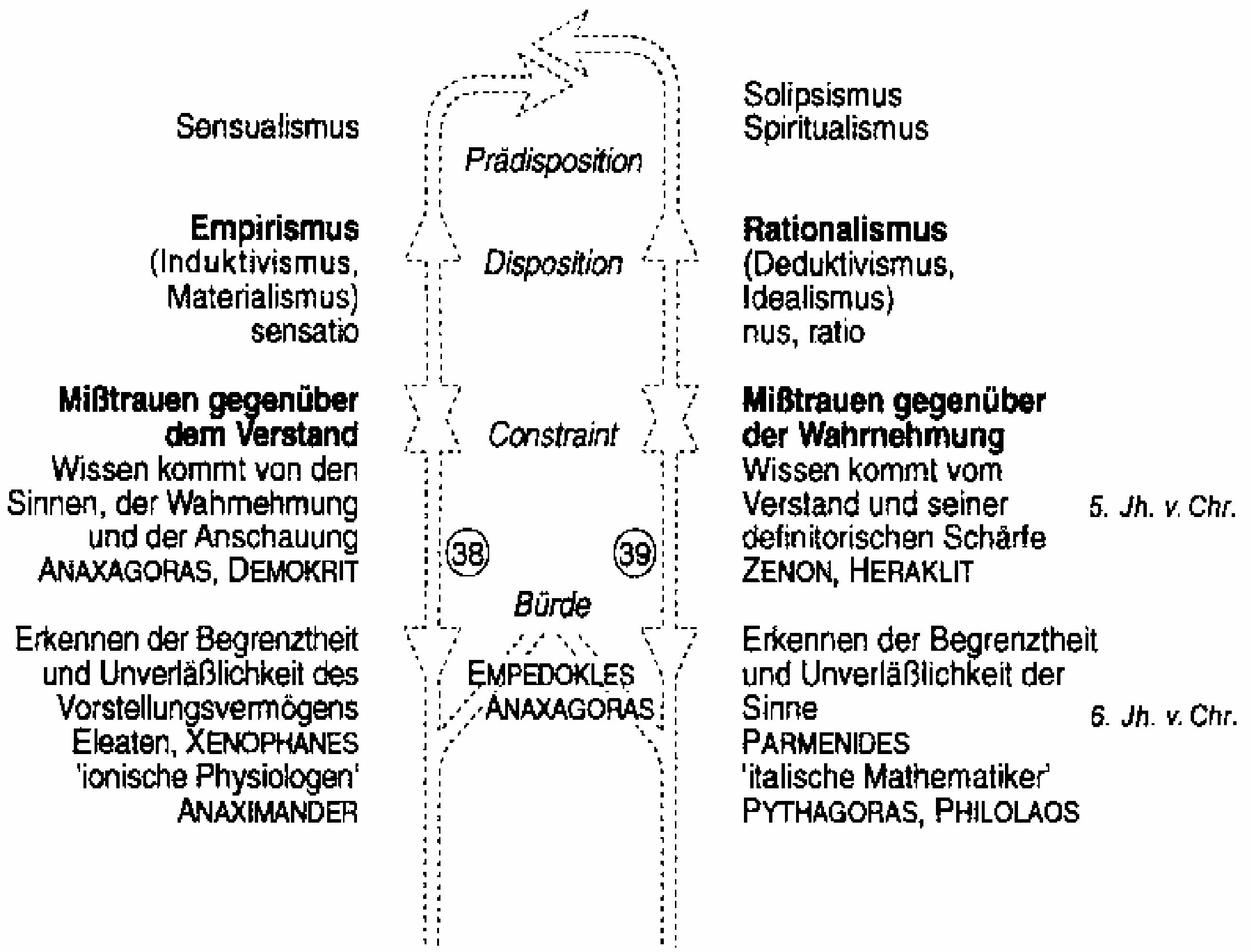


Abb. 38/39: BCD-*Serien zum Problem der Herkunft des Wissens*. Die Bürden wahrgenommener Begrenztheit der Vorstellung oder aber der Sinne führen bereits bei den Vorsokratikern entweder zu den Constraints eines Mißtrauens gegenüber dem Verstand oder aber der Wahrnehmung, mit den Dispositionen und Prädispositionen entweder zu Empirismus und Sensualismus oder aber zu Rationalismus und Spiritualismus.

Empirism and rationalism
(Riedl, Mit dem Kopf durch die Wand, 1994, 176)

6 Empirism – Rationalism 4

1) Empirism needs rationalism

Description of observation requires previous theories:
Pre-knowledge, "Vor-Urteile", not prejudice; language
"Theory determines which categories we can observe." (Einstein)

Kant's so-called Copernican turning point of metaphysics:
"Knowledge is not determined by the objects,
but the objects are determined by knowledge."
Modern: "The objects of cognition are determined
by human cognitive power (by human cognitive structures)."

2) Rationalism needs empirism

Categories are evolutionary phylogenetical experience

3) Kant's synthesis of empirism and rationalism:

transcendental epistemology/idealism:
"There must be basic principles of human cognition
(starting point) before and independent of any experience:

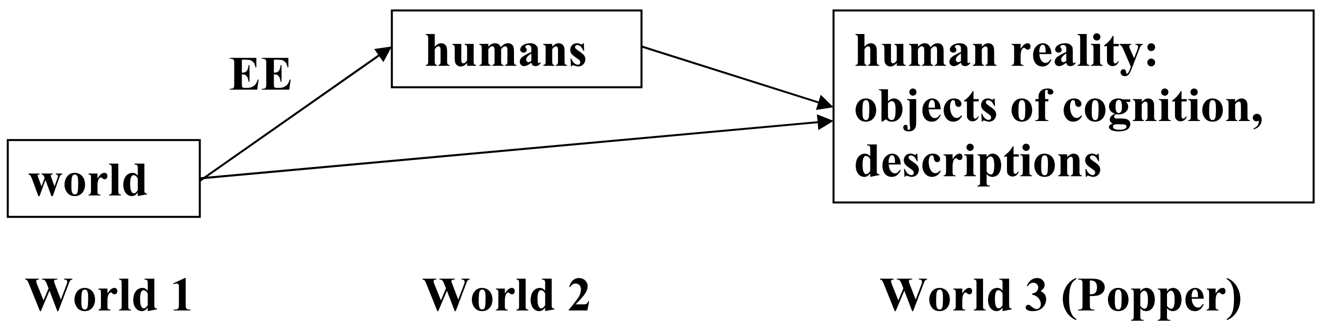
The ways/forms of human perceptive interpretation, "ideation"
("Anschauungsformen"),
the apriori of perception and thinking, called categories,
e.g. time, space, causality etc. "

"The categories decide upon what becomes object of cognition."

Are they adequate?
Yes, according to Kant, their origin is transcendental, there is
a pre-stabilized harmony between world and (human) categories.

A modern answer is not given before Evolutionary Epistemology.

6 Empirism – Rationalism 5: synthesis



Judgment of the relation
between world and humans and their cognitive equipment:
transcendental epistemology:
pre-established harmony due to transcendental influence
evolutionary epistemology:
adequacy due to evolution
as humans are a product of the world

Radical constructivism and solipsism
ignore the relation between world and human reality,
state that human reality is independent of a surrounding world

References

pdf-files of my own publications: see my homepage.

Holl, Alfred:
Empirische Wirtschaftsinformatik und evolutionäre Erkenntnistheorie.
In: Becker, Jörg et al. (ed.): *Wirtschaftsinformatik und Wissenschaftstheorie. Bestandsaufnahme und Perspektiven*.
Wiesbaden: Gabler 1999, 163-207, ISBN 3-409-12002-5.
English translation on my homepage.

Holl, Alfred; Maydt, Dominique:
Epistemological foundations of requirements engineering.
In: Erkollar, Alptekin (ed.): *Enterprise and business management. A handbook for educators, consulters and practitioners*.
Marburg: Tectum 2007, 31-58, ISBN 978-3-8288-9282-8
[extended congress paper for *Requirements Days, Nuremberg, Germany, May 2006*]

Holl, Alfred; Auerochs, Robert:
Analogisches Denken als Erkenntnisstrategie zur Modellbildung in der Wirtschaftsinformatik.
In: Frank, Ulrich (ed.): *Wissenschaftstheorie in Ökonomie und Wirtschaftsinformatik. Theoriebildung und –bewertung, Ontologien, Wissenmanagement*.
Wiesbaden: DUV 2004, 367-389, ISBN 3-8244-0738-8.

Holl, Alfred; Paetzold, Felix; Breun, Robert:
Cooperative cyclic-iterative knowledge gain in IS anti-aging.
Nuremberg: University of Applied Sciences 2011.

Holl, Alfred; Scholz, Michael:
Objektorientierung und Poppers Drei-Welten-Modell als Theoriekerne der Wirtschaftsinformatik.

In: Schütte, Reinhard et al. (ed.): ***Wirtschaftsinformatik und Wissenschaftstheorie. Grundpositionen und Theoriekerne. Arbeitsbericht 4 des Instituts für Produktion und industrielles Informationsmanagement*****.**
Essen: Universität 1999, 91-105 und 168 f.