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Information Systems as Empirical Science and Evolutionary Epistemology

Aim of the course

Formal mathematical models inevitably form the necessary basis for every computer program. As a result, it is important for the computer scientist to be profoundly conscious of the difference and the conflict between reality and formal models. This consciousness shall be developed by discussing different epistemological approaches and by examining special examples in information systems (IS).

Thus, the students shall acquire an increased epistemological understanding and the ability to consciously choose an appropriate epistemological theory for their future activities. In particular, they shall learn to renounce naive realism in favor of critical realism and of evolutionary epistemology for formal modeling in computer science.

Abstract

A great deal of the phenomena encountered in information systems cannot be explained completely and definitively by computer science itself. One must go beyond its borders and consult other disciplines: ergonomics, human resources psychology, sociology, epistemology. My considerations focus on questions leading particularly to epistemology.

Epistemology is the branch of philosophy which deals with the acquisition, nature and limits of knowledge. Scientific knowledge, such as the formal models necessary for implementing enterprise information systems on computers, is examined by both epistemology as well as by the theory of science, which is also a philosophical discipline. Its subject matter is the foundation of science in general and of its methods (i. e. scientific procedures with the aim of knowledge acquisition and knowledge judgement). So far, theory of science and epistemology overlap.

Computer science has only rarely been regarded from the aspect of its methodology (theory of scientific procedures). Therefore it is undoubtedly desirable to transfer epistemological considerations to computer science. This is especially true for information systems.

In the relevant epistemological branches, the preferred research objects are not the humanities or pure mathematics, but natural sciences. Physics, and, increasingly in modern times, biology, are the standard research objects, i. e. empirical sciences. In order to apply an epistemological way of thinking, which is formed by the empirical sciences, to information systems, a connection between information systems and the empirical sciences has to be found.

Chapter 1: The field "information systems" in itself can be understood as an empirical science, at least basically. This is because it includes just the essential empirical procedures: observation, description, modeling and the formalizing of models. These

procedures can be used as points of comparison to natural sciences: Formal models are the basic forms of knowledge in empirical sciences. Because of these comparisons, it makes sense to transfer epistemological considerations from natural sciences to information systems. This serves as the starting point for the further examination.

Chapter 2: Fundamental facts about the knowledge acquisition methods of empirical sciences will be presented in an overview. This overview can be presented quite concisely as approached from an epistemologically rather naive point of view. First, make observations, and then design models based on these observations. These models can be more or less well formalized, and the quality of these models has to be judged epistemologically. These explanations illustrate the results of Chapter 1 in more detail.

Next, the epistemology of natural sciences is applied to information systems. For this purpose, two different approaches are used. First, a deductive approach starts from the epistemological side (Chapter 3). Next, an inductive approach starts from the phenomena of information systems (Chapter 4).

Chapter 3: Epistemological positions which are of special value for the judgement of phenomena in information systems are presented. These positions are classified according to their estimation of the quality of human knowledge.

Popper's Three-Worlds-Theory ontologically distinguishes between three levels of existence for objects of cognition: nature, human consciousness and culture. It serves as an excellent classification schema for different epistemological opinions.

Critical realism considers the empirical world as accessible to cognition through a series of approximations. Restrictions result from the particularities and constraints of the human cognitive processes (knowledge acquisition).

Evolutionary epistemology is a biological interpretation of Kant's transcendental epistemology. It explains the good approximation of reality by human knowledge with the hitherto observable evolutionary advantages of humans. If his cognitive apparatus were unfit, homo sapiens would not have survived as a biological species. What is effective with regard to evolution, however, is not necessarily advantageous in designing formal models. Special types of behavior, which are considered as detrimental in fields such as in information systems, can be explained as cognitive strategies learnt during evolution.

Every epistemological approach has its special explanatory range and power. In order to judge a concrete phenomenon, the respectively simplest appropriate approach has to be used. This proposition is formulated as an epistemological step model.

Chapter 4: Problem areas in information systems are explained systematically and epistemologically on the basis of the approaches mentioned. These explanations are illustrated by selected phenomena, which shall serve as motivating examples. Finally, the resulting proposals for solutions, their advantageous effects and consequences for information systems are discussed.

The following problem areas are discussed: Particularities of human cognitive power and its consequences for the constitution of objects of cognition and the quality of knowledge, properties of objects of cognition, properties of subjects of cognition ('human factor'), and the interactions between them during observations.

Questions such as the following are discussed: Why is the design of new and better modeling techniques and tools always a current research topic? To which degree can they be improved? Does the search terminate with the invention of object-oriented techniques?

Epistemology finds answers to these questions through the fundamental examination of observation and modeling processes. These answers generally characterize the reasons and the nature of the inevitable discrepancies between reality and model.

Although there is no single all-encompassing result, which can be formulated in one sentence, there are a lot of partial results. In essence, we can say that while it is true that knowledge of epistemological connections does not eliminate the fundamental epistemological problems, it does, however, considerably reduce their undesired effects.

Overview

1. What is the connection between epistemological approaches in natural sciences and IS? The essential empirical methods to acquire knowledge as basis of comparison between IS and natural sciences

I would like to apply epistemological approaches from natural sciences to IS. Therefore, it is necessary to connect IS and natural sciences:

– Natural sciences are empirical sciences.

– IS can be interpreted as empirical science.

In spite of using an empirical point of view, I do not support a radical, naive empirism (i. e. experience alone decides upon the truth of statements). On the contrary, I thoroughly examine the cognitive processes during observation and model construction (see 3.2.5).

1.1 Thesis/proposition

IS can be interpreted as empirical science, at least in its essential branches. I will give reasons for my opinion in several steps.

1.2 What interpretation of IS is taken as basis?

I consider the following interpretation a starting point which most IS researchers could agree upon: IS has the task to optimize information handling processes (activity sequences) in enterprises, without destroying the particularities of the individual enterprises. The optimization is done mainly with, but also without using IT. Among others, it comprises the fields of business process optimization/reengineering (BPR) and conception of enterprise resource planning (ERP) systems.

1.3 What are the essential methods of empirical sciences?

I think a lot of readers will have an intuitive imagination of scientific or empirical methodology in general, so that there is no need to go into more detail at this time (see Chapter 2 for a more profound discussion).

Formal models are the essential forms of knowledge in empirical sciences. The methods which produce them, are observation, model construction and model formalization. Therefore, it can be recommended to examine IS with respect to these methods.

1.4 IS and methods in empirical sciences

1.4.1 Why do IS deal with observations?

Information handling processes in enterprises can have considerable particularities, depending on the respective enterprise and enterprise domain. They often are the basis for the enterprise's survival. Hence follows with the above IS interpretation: As a measure of optimization, it is not sufficient to introduce given enterprise models in grown enterprise structures. Instead, a difference between two methodical steps should be made:

1. At first, the information handling processes are formally modeled and optimized (exhaustion of the potential for organizational improvements and standardizations).
2. In a second step, the remaining particularities of the individual enterprise are registered in order to customize an ERP system.

Both steps have to be based on a precise description of the actual state in order to lead to successful results. A concept for a planned state does not appear from nowhere. This requires that enterprise staff and/or external consultants thoroughly observe the information handling processes.

1.4.2 Why do IS deal with models?

A real information handling process in an enterprise is described as a business process (BP) which is already a simple model, just as an entity or an object is a model of a real item. But it is impossible to individually observe every possible copy of an information handling process (for example the one which is started by the order with order number 4711). It is even less possible to register it individually in the description of the actual state. As a result, it is required to do more: General BP types (comparable with entity types, object types) have to be figured out (for example the BP type which is started by a certain order type). General statements of this kind constitute complex models.

1.4.3 Why do IS deal with formal models?

Models in natural languages can not be applied in IS, because a computer (hardware basis of an ERP system) is a formal machine and, therefore, does not understand statements in natural language:

"The range of interpretation has to be reduced to zero as soon as the handling of terms is transferred to machines which do know logics, but do not know hermeneutics, i. e. no method of understanding." (Wedekind 1980, 1269; free translation)

Even if using very comfortable programming environments, commands to a computer have to be given in a formal language (every programming language is such a formal language). For this reason, computer science inevitably needs formal models as basis for software (computer programs).

In the framework of software engineering, formal models with different degrees of formalization (called design, system plan, (application) concept, requirements specification etc.) form the end of the analytical phase (systems analysis) which is the essential cognitive process in IS. They serve as an interface to the synthetical phase (implementation, programming) and as a legal basis for the contract between end user and developer.

The motivation of statement 1.1 is now complete and will be summarized.

1.5 In what respect are IS and natural sciences comparable?

In natural sciences, particular natural phenomena are observed. Hence, formal models are constructed via model construction processes. They are necessary for a mathematical description of properties of nature. They serve both for a better understanding of these phenomena and as a basis for the prediction of similar phenomena.

In IS, particular copies of information handling processes in enterprises are observed. Once again, via model construction processes, formal models are constructed. They are necessary for the design of system plans which are used for the implementation of ERP systems on computers as formal machines. The formal models serve both for optimizing these information handling processes and for optimizing similar information handling processes in similar enterprises.

	natural sciences	IS
object of examination	phenomena of nature	information handling processes in enterprises
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 plans for ERP systems
indirect use	explanation, understanding	optimization of information handling processes
transferability	prediction	reference models

These rough parallels underline the following statement once more:

The crucial three methods, which IS and natural sciences have in common, are the essential knowledge gaining methods in empirical sciences:

observation, model construction and model formalization.

The comparability of the empirical methods in IS and in natural sciences is thus verified. It is the main basis for my considerations and the core motivation for further discussions of empirical methodology (especially from natural sciences) and for the examination of IS questions using an epistemology based on natural sciences.

I consider this examination urgently necessary and very effective. It shows the background of a lot of phenomena and presents them in a new aspect. Taking this positive view, I am obliged to try an answer to the question why IS researchers very rarely dedicate their considerations to epistemology.

1.6 Why is the conscious, explicit discussion of epistemology not a primary IS research field?

1. Computer science and especially IS are relatively young sciences without any broader consolidation. They only rarely do basic research, but they are more influenced by the immediate practical profit and by the applicability of their results (everyday job, feasibility and technological pragmatism).

2. Applied computer science (encompasses IS) often deals with largely pre-formalized (large preliminary formalization) object domains where the conflict reality vs. formal model is not (so) obvious (see 4.2.2 for details).

Example: Problems of numerical mathematics and accounting.

The gap between reality and model and therefore the necessity of dealing with epistemology often is not made aware and evident before formalizing object domains which are only little formalized or only little suitable for formalization.

3. As a simplification, applied computer science is sometimes interpreted as an exclusively auxiliary science (by itself and by the application field). Thus, it leaves the epistemological judgement of models to the application field and restricts itself to only preparing models for the implementation on a computer (pure software technology).

2. What happens when the knowledge-acquiring methods (observation, modeling and model formalization) are executed in empirical sciences? Fundamentals of the methodology of empirical sciences

According to thesis 1.1, IS can be regarded as an empirical science. Therefore, Chapter 2 is dedicated to the fundamental considerations of the methodology (science of the knowledge acquiring methods) in empirical sciences. Thus, my thesis is explained more precisely and in more detail. Because I start here from an epistemologically still very naive point of view, a concise overview is possible.

2.1 Observations

2.1.1 Which objects are observed and how?

We deal with phenomena which can be observed with human sensory perception or with more or less complicated technical equipment (for example with measuring instruments).

2.1.2 How does an observer select the phenomena for his observation?

A phenomenon is selected for observation by conscious action, intention and control. In some cases it is even produced (so called experiments). Observation happens neither passively, nor arbitrarily, nor by accident.

2.2 Scientific models and their acquisition

2.2.1 Why do you have to go beyond particular observations in empirical sciences?

In empirical sciences, knowledge should be acquired which makes it possible to give better explanations and predictions for classes of similar phenomena in an object domain. As it is not practical to individually observe every possible particular phenomenon, you have to find another way.

2.2.2 What kind of knowledge is acquired by particular observations?

Starting from the observation of similar, comparable, representative particular phenomena of a given object domain, you try to gain general laws and connections (statements, propositions, rules). They should permit predictions on other particular phenomena of the same kind.

General laws of an object domain are forms of scientific knowledge and can be called ‘scientific models’. This terminology is not unique; the word ‘theory’ is often used as well; I consider differences between the two expressions as artificial.

The construction of scientific models requires a scientific modeling intention.

Scientific models can have different size and complexity (for example simple mathematical formulas vs. business process models and enterprise data models).

2.2.3 Aside: Differentiation of the concept of a model: Which predecessors of a scientific model can be differentiated?

Due to the classification properties of language (giving names and constructing sets), descriptions in natural language automatically have the appearance of a model without being based on a certain modeling intention. I call them premodels (4.1.1.5).

Furthermore, non-scientific models (for example model railway, doll) have to be mentioned. It is true that there is a modeling intention but not a specifically scientific one.

2.2.4 How are scientific models acquired from particular observations?

The acquisition of general statements requires abstraction from the accidentials (contingencies) of a particular phenomenon and construction of ideal types. The induction, which finally leads to more general statements, is a creative human act. That is why there are no scientific models without humans as model designers. Induction happens as inspiration, as an idea, as a flash of genius, is not objectifable. Details can scarcely be explained and followed consciously.

Example: In 1980, I was able to participate in a guest lecture of the elderly physicist Friedrich Hund (1895 – 1997). He was asked, how he got the idea of his Hund's Rule on electron configurations in non-closed spheres, and answered: by staring at the spectra.

2.2.5 How are scientific models verified and corrected?

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

Model construction (induction) and model test (deduction) are executed iteratively in a cercular process. It is called a maieutic cycle (according to the ancient greek word for midwifery):

1. A model is inductively constructed/modified by a creative act.
2. Deductively, predictions are derived from the model. Experiments for their test (and therefore the model's test) are designed.
3. The experiments are done.
4. The new observation data are interpreted, compared with the predictions, evaluated and classified.

(1./3. Empiristic part, 2./4. Rationalistic part; see 3.2.5)

These considerations are the basis for Karl Popper's fallibilism (3.2.4): A model is derived from comparatively few observations. By extension of its domain (mathematically spoken), the model can be applied to particular phenomena which did not serve as its starting point. Therefore, it is a principle that you can never exclude the occurrence of a particular phenomenon which might falsify (disprove) the model via modus tollens.

Example: The statement, that all swans are white, can be considered as correct until a black one is observed.

2.2.6 Are scientific models unique?

There are two important facts: the inductive inspiration and the fact that there is no unique answer to the induction question. They imply that it is always possible to construct different models for an object domain. At this time, I cannot explain the possible relations between different models of one and the same object domain.

2.2.7 Notation of models

2.2.7.1 How are scientific models described?

Models have a scientific value if and only if they are represented in a language. Only thus can they be communicated to others, are they public, can they be followed, reproduced, discussed and therefore used scientifically.

Trivially, models can always be formulated in natural language (English, German etc.). Besides natural languages, you can partly also use formal languages for model representation.

In a narrow sense, the language of mathematics and logics is usually called formal language. In a wider sense, this term can also be used within computer science for programming languages and the notation semantics of various graphical representation techniques (such as decision tables, entity relationship (ER) diagrams; moreover technical drawings).

2.2.7.2 In what respect do natural and formal language differ?

Due to space limitations, this question cannot be discussed in detail. I only mention three differences which are crucial in this context.

In many scientific branches, natural languages are not suitable for exact model representation because of their lack of precision:

1. Due to the metaphoric use of words and the broad spectrum of possible meanings of every word, the following situation is normal: Ambiguity (polysemy, homonymy) of words and the reduction to one meaning only by the context.
2. Fundamental diachronic instability of the words' meanings.
3. Stress dependence of a phrase's meaning (subject-object-sequence also for questions).

But natural languages already possess certain formalization approaches (pre-formal properties) (4.1.1.5):

1. Standard word meanings, basic meanings.
2. A certain diachronic stability (you can still understand Shakespeare).
3. Standard phrase meanings (subject-object-sequence only for statements).

If more precise, more economic, more comprehensible and more elegant model representations are required it is necessary to use formal languages or even to construct languages of this type. Nevertheless, natural languages are the basis for the design of formal languages (in spite of their lack of formality). Without the existence of natural languages and their approximations of formalizations, one would not have had the idea to design formal artificial languages. In contrast to natural languages, the formal ones are characterized by:

1. Unique meanings of words, no ambiguities (polysemies, homonymies), well-defined construction of terms.
2. Temporal stability of the words' meanings by convention.
3. Uniquely defined phrase meanings by the sequence of the parts of speech.

2.3 Formal optimization of scientific models

2.3.1 Formal optimization of scientific models: Why? How? All?

The didactical objective of formal optimization is to improve the possibility to follow, understand, test and discuss a model.

The syntactical objective is to improve aesthetics, elegance, comprehensibility and brevity of a model's representation.

The formal optimization of scientific models is done in three steps:

1. Formalization: formulate in formal language.
2. Mathematization: bring about mathematical correctness.
3. Axiomization: bring about exemption of redundancies.

After the first step, the model is formal, after the second mathematical, after the third axiomized.

Not only formal models are scientific. It depends on the object domain and on the modeling purpose whether a formalization is useful. Therefore, it cannot be the aim to formalize every model.

Example: Philological or theological models are less suitable for a formalization.

2.3.2 Under what conditions is a natural-formal language translation possible?

Not every statement in natural language can be expressed in formal language. Formal language is far from possessing the expressive power of natural language. It can only describe those phenomena which are suitable for formalization (can be described in formal language). Consequence: Suitability for formalization depends on the properties of the individual object domain. Moreover, not every object domain can be formalized up to the same degree (see 4.2.2 for details).

Formalizations are human constructions, of course. According to experience, however, not every object domain can be formalized. Therefore, there are particular properties of the object domain itself which appear to the subject of cognition as suitability for formalization (this is a description category, 3.1.3)

Example: The phrase "the leaves of this tree move in the wind" in natural language is not suitable for formalization. Already the reality reference contained in 'this' flees formalizing, much more the description of the complexity of the movement.

2.3.3 Why are models formalized?

Formalization is the first step to the formal optimization of scientific models. The result is a formal model. Reasons for this procedure are:

1. The application of formal language offers the advantages mentioned in 2.2.7.2.
2. A representation in formal language requires more precise consideration than one in natural language, as it is normal that natural language always causes a certain lack of precision of thinking, even if the model designer does not intend it and uses natural language in a very concise way.
3. Formality makes mathematization (2.3.4) considerably easier.
4. A pragmatical reason for formalizing a model can also be that it shall serve as the basis for a computer program within applied computer science (1.4.3).

2.3.4 Why are models mathematized?

Mathematization is the second step of formal optimization and consists in constructing a mathematical model. Formality does not yet imply logical consistency and is in so far premathematical. That is why formal models are made more perfect in order to achieve mathematical correctness. It consists of:

1. Consistency: The model does not contain any internal contradiction (formality does not guarantee the exemption of contradictions).
2. Explicity: Nothing (except axioms, 2.3.5) is considered a self-evident prerequisite. There are no implicit assumptions and pre-conditions which are regarded as intuitively obvious.
3. Completeness: There are for example no missing branches in case differentiations (for example IF THEN ELSE).

If a formal model consists only of a simple mathematical formula, it is trivially a mathematical model. The impact of mathematization does not become evident before dealing with more complex models.

2.3.5 Why are models axiomized?

The third step of formal model optimization leads to an axiomized model and is done by explicit axiomization. The statements (propositions) of a mathematical model are reduced to axioms, that is, underlying propositions. They have the function of fundamental assumptions and are not proved. In this way, the brevity of a mathematical model is further enlarged. Exemption of redundancies (logical independence of axioms: no axiom can be derived from the others) is achieved.

Example: An ER model is formal, but not axiomized. The mathematical optimization is done by constructing a model in the third normal form (3NF; not only for relational data bases!). The normalization reduces uncontrolled redundancies to controlled ones.

2.3.6 What kind of mathematics is necessary when formalizing and mathematizing models?

2.3.6.1 Creative vs. reproductive

For not or only partly formalized (mathematized) object domains, creative mathematics establish well-defined (a definition is not mathematically well-defined by itself!) new terminological definitions (in form of concept axioms) and selects suitable mathematical concepts for the further description. Exclusively reproductive mathematics is not sufficient for the formalization of models, as it is restricted to the application of definitions, propositions and algorithms (2.3.6.3).

2.3.6.2 Referencing reality vs. speculative

Mathematical models are based on properties of reality, as usual with regard to applied mathematics and the axiom systems of Hilbert (Euclidean two-dimensional geometry) and Peano (natural numbers). There is not any arbitrary, speculative definition of axioms.

2.3.6.3 Simple vs. complex

In IS, only very specific simple mathematical concepts are used – often related to natural language – such as function, Cartesian product, equivalence relation. Profound mathematical concepts are not used. The reasons for this situation have to be figured out in another discussion.

2.4 What is the explanatory value of mathematical models?

They describe the mathematical properties of phenomena (the question of *what* happens) in detail and permit predictions. In so far they have an explanatory value. But they cannot give any information about *how* the mechanisms work which are responsible for the phenomena.

“Physics is mathematical, not because we know so much about the physical world, but we know so little: it is only its mathematical properties that we can discover.” (Russell 1927,163)

This consideration will be continued in 4.1.1.3 (functional models).

Example: With the mathematical description of gravity (free fall), we are able to compute falling periods, but we do not gain any information about the mechanism of gravity, that is, how the earth exerts gravitational force on a solid.

3. Which epistemological approaches lead to useful answers to the epistemological questions of IS?
Epistemological approaches with relevance for IS

3.1 Which levels of existence of objects of cognition are possible?
Differentiation according to the object of cognition (ontological)
Popper’s theory of 3 worlds

I consider it an excellent epistemological model which at the same time is an excellent schema for the classification of diverse epistemological approaches (3.2). In his book ‘Objective Knowledge’ (1973, 158 ff.), Popper makes a difference between three levels of existence for objects of cognition (object domains). A specific way of existence corresponds to each of them.

3.1.1 The three worlds in Popper’s theory of the 3 worlds

3.1.1.1 World 1: ‘Nature’, natural universe, real world

It is defined as the empirical world of the sensorily perceptible objects. It encompasses the natural physical-chemical-biological world as well as the social-economical-technical world (for example information handling processes in enterprises). The latter seems to be natural to the naive observer, but it is constructed by humans.

3.1.1.2 World 3: 'Culture', discursive universe, world of concepts and models

It is defined as the conceptual world of the mentally perceptible objects, the existing and imaginable objects of thinking (for example questions about the properties of mathematical objects which arise from their very definition). It is the unintended result of the history of the human mind, which is a constructionist creation of humans (in contrast to the Platonic view of a pre-existing world of ideas that you just have to remember by anamnesis). It can be described with language and encompasses (Platonic) ideas, 'things in themselves', cultural concepts, languages (as description frameworks for world 1), contents of libraries, problem descriptions, critical arguments, observation frameworks, abstract conceptions, mathematical objects, mathematically true and false statements, models of every kind in empirical sciences (for example physical formulae, business process models, enterprise data models).

From a synchronic point of view, the contents of world 3 are pluralistic, heterogeneous and complex. They can be incoherent (for example incompatible models) and logically inconsistent. From a diachronic point of view, the world 3 elements are temporally dynamic (unstable) and discontinuous (not upwardly compatible). From this situation, homemade apories (unsolvable contradictions) can arise.

The dichotomy (splitting) in world 1 and world 3 is known from classical antiquity. Popper extends it by introducing:

3.1.1.3 World 2: Individual consciousness of a human being

It is defined as the subjective, personal, mental-psychic world of the actions and experiences of an individual. Every individual has his own world 2, of course. It encompasses states of consciousness and dispositions for actions as well as non-verbal <u>world 1 images</u>, their verbal descriptions (world 3) and verbal <u>world 3 activations</u> (individual knowledge and ideologies). They all interact and interfere (3.1.2). By introducing the terms of image and activation, I go beyond Popper's published opinion.

3.1.2 Interrelations between Popper's three worlds

3.1.2.1 Which interrelations exist between world 1 and world 2?

World 1 is accessible to humans via non-verbal world 1 images. They are produced by unconsciously abstracting and filtering sensory perception and are verbally described by world 3 concepts.

3.1.2.2 Which interrelations exist between world 2 and world 3?

In his ontogenesis, a single human is not able to personally follow the whole history of the human mind (phylogenesis), that is, to create world 3 once more on his own. Therefore, he is confronted with its results (that is, the world 3 objects), he has to learn them partly (for example when he learns a language) and has to establish world 3 activations of his own. Thus, world 3 is not fiction for the individual, but really exists, although in another way than world 1. As world 3 also contains imaginable objects of thinking (3.1.1.2), it gains a certain autonomy. Thus, world 3 transcends and re-affects human thinking. Without worlds 2, which activate world 3 parts, learn them, make use of them, world 3 is dead, such as the contents of an unread book, an unused library or an internet without surfers.

Vice-versa, every individual contributes to a change of world 3 by communicating his world 3 creations to others, for example by defining special terms when designing models or simply by constructing models.

3.1.2.3 Which interrelations exist between world 3 and world 1?

In both directions, there is only an indirect relation, arranged via world 2.

Humans (world 2) can use theories from world 3, such as technical know how, all sorts of socio-economical organizations, mathematical structures (for example accounting), in order to give the world of their lives (world 1) a (new) shape.

Vice-versa, world 1 exerts an influence on world 3 because humans always construct new description categories for their world 1 understanding.

3.1.3 How can the concept of models be integrated in Popper's theory of 3 worlds?

Both already existing and recently created world 3 concepts (meta-level) serve humans as description categories (cognitive categories or formal categories in formal models) for immanent categories (real categories) of world 1 (object level). In this sense, models are more or less complex description categories which consist of simple world 3 concepts (verbal elements). They aid in understanding world 1.

World 3 supplies a lot of description categories (observation frameworks, interpretation patterns, abstractions and filters in form of pre-knowledge or prejudices). Thus on the one hand, it supports the verbal world 1 description, on the other hand however, it exerts a strong influence on it.

Due to the enormous complexity of existing and imaginable description categories, models do not form any homogeneous, continuous partial existence level within world 3, but a very differentiated structure: It encompasses completely different abstraction levels, (for example SA levels) with intersections, coverings, feedbacks, hierarchies at the same time. Every model itself can serve as the basis for a more abstract one.

These considerations will be continued in 4.1.

3.1.4 Popper's consequences from his theory of 3 worlds

I agree with Popper's view of the cognitive accessibility of world 1, a critical realism in the form of a critical rationalism (fallibilism). I will further discuss it in Chapter 4. But I cannot accept his very objectivistic estimation of world 3 where he assumes the existence of knowledge even without a subject of cognition (Popper 1972, 112). In this respect, I tend to a moderate constructivism (in contrast to a radical one; not to mix up with the logical one (constructive theory of science); this only in order to be complete).

3.2 Which epistemological approaches are relevant for empirical sciences, especially for IS?
Critical realism and evolutionary epistemology

Diverse epistemological approaches differ in their answer to certain crucial questions about qualities of human knowledge. These questions are very well suited to giving structure to 3.2. From the very beginning of my discussion, I omit approaches which I consider as not suitable for empirical sciences (and therefore for IS). I only mention such approaches which seem likely to succeed and to support pedagogical presentation.

3.2.1 Which of Popper's three levels of existence is accessible to cognition?

IS deals with objects of cognition in world 1 (enterprises). Therefore, an epistemological approach is required which considers them as accessible to cognition, that is, realism (but only a particular variant).

3.2.2 In what way is world 1 accessible to cognition?

World 1 is only indirectly accessible to humans: by active, unconsciously and non-verbally interpreting and filtering sensory perception and by verbal description with world 3 concepts (cf. 4.1.1). This view is taken by critical realism and evolutionary epistemology (a particular form of critical realism). The second opinion weakens the consequences of this view a little: During evolution, the knowlege gaining structures of humans develop in adaptation to the modalities of perception, humans are not helpless in the power of the latter. Contrary to that, naive realism takes the view of a direct cognitive accessibility of world 1 by being passive, only photographing and thoroughly representing sensory perception and ignores research results within sensory and neural physiology.

3.2.3 In what quality and to what degree is world 1 accessible to cognition?

A useful approach for IS must at least assume an approximative cognitive accessibility of world 1, as critical realism does. Evolutionary epistemology advocates this point of view by stating that humans would not have survived during the biological evolution if their cognitive structures were unfit and if they could not even approximatively understand world 1: The human cognitive apparatus cannot commit existence threatening mistakes. A consequence of the distortion by interpreting cognitive processes is that world 1 is not completely accessible to human cognition (naive realism states the contrary).

3.2.4 Is definite, objective knowledge of world 1 possible?

The inspirations of induction and the distortion effects of perception forbid a radical objectivism. Neither is a pure relativism adequate for IS, as it denies definite objective knowledge overall without making any differences. It is recommended for IS to assume the possibility of an approximative knowlegde which is variably definite depending on the respective object domain. This is the view of Popper's fallibilism (critical rationalism; 2.2.5). It is a particular form of critical realism. This point of view leads to a concept of truth which can only be defined in relation to a certain reference frame.

3.2.5 Which source of knowledge settles the truth of statements?

Naive rationalism mentions reason and deduction as the only criteria for settling the truth of statements, naive empirism only experience and induction. None of these views is correct; this is made obvious by the interplay of empiristic and rationalistic components during the maieutic cycle (2.2.5) and in the interaction of Popper's three worlds (3.1.2, see also 4.4):

1. Observation frameworks (intellect) exert an influence on the selection of observation objects, on observations and on observation interpretations.
2. Observations (experiences) change observation frameworks.

Kant tried to bring the two views together. His transcendental epistemology/idealism lead to the so-called Copernican turning point of metaphysics. The statement was:

"Knowledge is not determined by the objects, but the objects are determined by knowledge." Formulated in a more modern way: "The objects of cognition are determined by human cognitive power (by human cognitive structures)." (see also 4.1)

Hence, there must be basic principles of human cognition which do not require any experience. They are apriori as Kant says: He calls them the apriori (the pre-conditions) of perception and thinking, the latter called categories. Kant means by apriori for example the basic principles of spatial and temporal perception and of causal thinking. Therefore, his basic statement can also be formulated this way: "Only those things can be objects of experience which are determined by the (divine) order of categories."

3.2.6 Where does Kant's apriori originate?

As the name "transcendental epistemology/idealism" suggests, Kant assumes a supernatural, transcendental origin of the apriori (of the innate ideas). From a biological point of view, evolutionary epistemology easily finds a natural, phylogenetic origin: The apriori consists of the human sensory, neural and cerebral physiological structures. This apparatus produces a view of the world (Lorenz) and is a result of evolution. The apriori (pre-conditions) of the ontogenesis is the aposteriori (results) of the phylogenesis.

Evolutionary epistemology was systematically founded by Konrad Lorenz (1941) in his classical paper "Kant's theory of the apriori revised/reinterpreted by present-day biology". Already at the end of the 19^{th} century, there were predecessors, such as the Viennese physicists Ludwig Boltzmann, Hermann von Helmholtz and Ernst Mach. Today, this view is above all taken by Rupert Riedl, a Lorenz disciple in Austria, and by Gerhard Vollmer in Germany.

3.3 What are the features of critical realism and evolutionary epistemology?
In what respect are different approaches compatible?
Epistemological step model

Now we have figured out the epistemological approaches which are essential for IS. They will be examined with respect to their compatibility and their particular explanatory values.

3.3.1 In what respect are different epistemological approaches compatible?
Thesis: step model

The selection of an adequate epistemological explanatory approach depends on the object of cognition and on the actual question (differentiated according to object domains, casuistical, eclectical). All three have to fit together. Depending on the special constellation, the most simple, suitable approach has to be chosen.

Example: The cognitive problems have other qualities when describing a house, or when describing sub-atomic particles, or when describing the information handling processes in an enterprise.

Only compatible, coherent approaches can be combined in a step model.

Example: The wave model and the particle model in sub-atomic physics are not coherent.

3.3.2 What are the features of naive realism?

It is the simplest epistemological approach at all, but basically sufficient for handling the everyday physical world. As soon as marginal domains (for example optical illusions) or the everyday social world (for example enterprises as objects of cognition in IS) or sub-atomic particles are in question, however, a naive-realistic view will soon turn out to be insufficient (see also 4.1).

Therefore, naive realism cannot be applied to problems of IS. Nevertheless, I mention it in this place for two reasons:

1. In this step model, it is the simplest approach which is suitable for everyday life.
2. It can unfortunately be found everywhere in the minds of naive computer scientists. And it is just the advocates of 'modern' modeling techniques who spread it. (Hereby I do not at all reject modeling techniques such as object orientation and CASE, but I do reject misinterpretations of their usefulness and their power).

3.3.3 What are the features of critical realism?

It can be interpreted as a coherent, upwardly compatible extension of naive realism (from this point of view, the latter is a special form of critical realism for 'simple' objects of cognition, where the conflict between reality and perceived image does not have any evident consequences). A close relation to critical rationalism (fallibilism) can be noticed. It is characteristic for critical realism to take a differentiated view (see 3.2.4) between the hard positions of the radical naive objectivism and the radical naive relativism.

Starting from observed phenomena in sub-atomic physics, the interaction between observer and observed object is emphasized. That is why a hard epistemological separation between subject and object is rejected (see 4.4). The following view is taken instead:. Differences in perception are due to differences in the object domain which consists of subject (observer) and object (observed item). The observer is part of the object domain, which he observes, and his disposition can exert an influence on the observation.

Example: Put your left hand in cold water, your right in tolerably hot. Then put both hands in warm water. Your left hand will perceive it as warmer than your right. The difference in the perception of temperature will last a couple of seconds.

3.3.4 What are the features of evolutionary epistemology?

It is a coherent, upwardly compatible extension of critical realism, from a biological point of view. Critical realism simply has to take notice of phenomena which evolutionary epistemology can explain and illustrate from its phylogenetic insight.

Due to the hitherto evolutionary success of human thinking, evolutionary epistemology takes a positive view of it. This leads to the assumption that human knowledge approximates the world quite well - within certain boundaries (3.2.3). Therefore, human ways of thinking are not regarded from an evaluating, prescriptive and normative point of view, but rather from a neutral and descriptive one: How do humans think due to their perceptional functions and cerebral structures? Thus, evolutionary epistemology can explain certain peculiarities of human intellectual power with cognitive structures and strategies which were learnt during evolution. In some other fields, these peculiarities are regarded as mistakes, dangers and absurdities.

Example: Why is naive realism the original, primary epistemological view? Human cognitive power (as biological property) is primarily determined by the everyday physical world (Vollmer's 'mesocosmos'), where naive-realistic interpretations are sufficient in most cases. The primary epistemological point of view, that is naive realism, is a result of the naive-realistic basis of human cognitive power (see also 4.1.2).

As a consequence of this consideration, you can even say: There is a parallel between the spectrum of the epistemological approaches and the spectrum of human cognitive power.

3.3.5 What are the features of radical and moderate constructivism?

[under construction]

3.4 Fundamentals of evolution

[only illustrations for a talk]

4. Which problem areas of IS require an application of epistemology? Which answers do critical realism and evolutionary epistemology lead to? Which advantages and which consequences for IS are the result? Selected examples, approaches for explanation and proposals for solution

After the presentation of suitable epistemological points of view, the application of epistemology in IS shall now be illustrated systematically. The problem fields are classified according to a simple epistemological schema. As in every intellectual classification, overlaps and interdependencies are inevitably produced. The selected phenomena serve as illustrations and examples. The estimation of their importance may vary, depending on the reader's personal experiences.

4.1 result of observation: knowledge

4.2 object of observation 4.3 observer (subject)

4.4 observation process

4.1 What are the particularities of human cognitive power? How do humans gain objects of cognition? What are the qualities of human knowledge? Two epistemological dilemma: Problem of isomorphy and problem of isolation

Human cognitive power (the capacities, possibilities, strategies, ways and constraints of human knowledge acquisition) determines the objects of cognition. (Already Kant knew that they do not appear from nowhere (3.2.5).) On the other hand, cognitive power indirectly determines the quality of knowledge as well because humans can only gain knowledge about objects of cognition which are defined by cognitive power.

Although evolutionary epistemology regards human cognitive structures as effective (3.2.3) we have to consider the following two dilemma in a dicussion of how objects of cognition are defined. They result from the cognitive requirement of complexity reduction and imply qualitative particularities of knowledge.

4.1.1: Interpretation, abstraction, induction → problem of isomorphy

4.1.2: (not unique) decomposition → problem of isolation

4.1.1 Dilemma 1: Necessity of filtering, interpreting, abstracting, inductive cognitive processes: Problem of isomorphy world – model;

4.1.1.1 Phenomena

1. Why is there a permanent search for new modeling methods?

2. Why cannot even object-orientied modeling have the desired and promised result, that is, the one-to-one mapping of the reality?

4.1.1.2 Explanation by critical realism

Humans need knowledge about world 1, but do not have a direct cognitive access to it, but only to world 1 images in world 2. The latter are produced by filtering and interpreting perception processes and are verbally described with world 3 concepts (3.2.2) (immediate objects of cognition in world 2 and world 3). They permit an indirect (the only!) cognitive access to world 1 (mediate objects of cognition).

The gap ('distance') between world 1 and world 3 has to be bridged: A multi-stage, complex, knowledge-gaining process has to be executed until humans arrive at scientific knowledge:

1. Filtering and interpretation by sensory perception (for example retinal abstraction)→ world 1 images (non-verbal) in world 2
2. Denomination and interpretation by means of natural language (re-impact of existing world 3 concepts) → verbal descriptions of world 1 images in world 3 (pre-models)
3. Scientific modeling intention, abstraction, induction, typification, definition of terminology → scientific models
4. Formalization → formal models (depending on the object domain; 2.3.2, 4.2.2)
5. Mathematization → mathematical models

Due to the distortions in the single stages, the natural result is an inevitable discrepancy, an inevitable conflict between model and object domain in world 1. The conflict increases with the number of stages, especially by formalization. The respective structure components (immanent categories of world 1 and descriptive categories of world 3) do not at all necessarily correspond to each other. This lack of structural equality (isomorphy) causes the problem of isomorphy: Humans must acquire knowledge about world 1 and can do this only via world 2, although the thus acquired knowledge need not correspond to the immanent facts of world 1. If you are very lucky, you approximate the unreachable isomorphy by homomorphy (structural similarity).

4.1.1.3 Explanation by evolutionary epistemology

After critical realism has stated the facts, evolutionary epistemology can be asked for an illustration.

Human cognitive power and, as a consequence, the quality of human knowledge is determined by the biological purpose of knowledge. Its task is to guarantee the survival of humans in world 1 and its everyday situations and to gain advantages for survival; its task is not to understand world 1.

During evolution, it is not necessary for survival to understand, *how* the world 1 mechanisms work in detail (models with structural equality), but only *what* its effects are (functional models): In the latter sense, models always have an epistemological value (2.4).

4.1.1.4 Approach to explain the mentioned IS phenomena

Phenomenon 1: The problem of isomorphy is fundamentally unsolvable and cannot be overcome by any method (neither by object-oriented techniques). Approaches of that kind are reminiscent of the innumerable trials to square a circle, at a time when the fundamental unsolvability of the problem had been proved for a long time. Modeling methods and tools cannot solve fundamental epistemological conflicts. Therefore you should not run after trends of fashion which are superficial from an epistemological point of view.

Phenomenon 2: Real objects (world 1) and entities (or OO objects; changing labels does not change facts) face each other in the sense of the problem of isomorphy. The latter are descriptive categories (world 3). They are not all around us and cannot be found as immanent categories (world 1) in a naive-realistic way (such as seafarers discovered islands and continents which also existed without anyone knowing about them), but they are invented in a constructionist way and constituted by attributes (and OO methods), not only by names. They are human artifacts.

The same discrepancy is true for (real) information handling processes in enterprises and (formal) business processes in event-controlled process chain (EPC) models and (formal) use cases in UML-based OO-models.

The methods of entity-relationship or object-oriented modeling demand suitably defined entities or OO-objects as input. They cannot do the human job of defining descriptive categories (3.1.3). In this respect, the techniques mentioned are often applied without any reflection.

4.1.1.5 Proposal for solution

In spite of the unsolvable problem of isomorphy, an IS expert has to design formal models, of course, and he can do this quite successfully in an approximative way. But this requires a well-reasoned set of methods (see also 4.3.2.1):

Formal models have two starting points:

1. Reference models of other world 1 object domains in formal language.
2. Accurate, reflected observation of the inspected world 1 object domain and – derived from this – pre-models (2.2.3) in natural language.

On the basis of these starting points, you should proceed as follows:

1. Suitable reference models (not only one) have to be looked for and have to be transferred to the inspected world 1 object domain by analogy.
2. Due to the rudimentary formalization in natural languages, pre-models contain punctual, "atomical" pre-formal structures (2.2.7.2) as kernels of cristallization or condensation for formal modeling. The pre-formal structures have to be examined with respect to their formal adequacy. Descriptive categories, which are based on them or go beyond them, have to be constructed in a formally well-defined way.
3. Combination of reference model parts and individual model parts: Several alternative models have to be discussed (in writing), compared, validated and optimized.

According to my experience, it is an excellent testing possibility to assume the hypothesis of coherence: It consists in the simplification that the IS object domains can be described in a homogeneous and compact way. This is not necessarily so in object domains of physics, for example incoherence of models in the wave-particle dualism. From this hypothesis, it follows that different alternative models may not contain fundamental semantical inconsistencies, but that they have to be compatible.

4.1.2 Dilemma 2: Necessity and lack of uniqueness of a decomposition (structuring) of the world: Problem of isolation

4.1.2.1 Phenomena

1. Why is it impossible to find hard and clear boundaries of enterprises and their departments?

2. Why can it occur that an isolated IT-system does not at all solve the original problem?

4.1.2.2 Explanation by critical realism

Decomposition (structuring) is a prerequisite for a reduction of complexity. The latter is necessary for any knowledge at all. Humans have to structure their world 1 images (world 1 chaos vs. world 3 cosmos) in order to reduce their complexity. They have to divide the images into a lot of components, otherwise their human cognitive power is not able to cope with them. It is quite natural that the procedure of decomposition destroys interdependencies between the components.

Therefore, humans try to use their "cognitive scissors" only in those places of their world 1 images where they suppose only a few connections, which they consider as negligible from an idealistic point of view. In a naive-realistic manner, they transfer this supposition to world 1. More or less arbitrarily, they delimit components/segments (which, for instance, can encompass processes, items, informations), isolate them from their interdependencies and "cut" them out artificially. Thus, a dilemma arises which I call the problem of isolation: Humans have to acquire knowledge about world 1, but they can do this only via decompositions which, on the other hand, neglect interdependencies.

Humans construct systems which belong to world 2 or to world 3 when they are described verbally. Humans believe in a naive-realistic way that systems belong to world 1. But from our point of view, systems are special kinds of models, descriptive categories which shall approximate immanent categories.

Structuring is continued on the following lower level. Humans give an internal structure (order) to systems by dividing them into interacting components (therefore, a system is more than the sum of its components). The internal connections (between the components) shall be stronger than the external connections (of the whole system to its surroundings). The components can now be interpreted as (sub/partial) systems in their turn. The decomposition process continues on diverse abstraction levels.

4.1.2.3 Explanation by evolutionary epistemology

It is true that there are no natural, closed (self-contained) systems without interactions, but there must be systemlike structures with strong internal connections and weak external ones (‘open systems’); otherwise the cognitive use of segmentations of that kind would have been eliminated during evolution. Cognitive processes are carried out in the human cerebral cortex, which has its phylogenetical origin in optical nerval centers. Therefore, the starting point of the system concept can be found in optical-tangible items, whose visual contours coincide with their tangible boundaries. Physically spoken, they are solids (for instance apples, stones) with very strong internal connections and comparably weak external ones. They can be moved in relation to other items. Items of that kind can be comprehended in a naive-realistic way (cf. 3.3.4 naive-realism as primary epistemological view). Although mesocosmically determined, the system concept is transferred to other objects of cognition, for instance enterprises or departments, where it is only applicable with the necessary restrictions and modifications.

Tendencies to define very narrow system limitations have the advantage that, in comparison to big ones, smaller structure segments are less complex and better comprehensible as well as more effective as the basis of analogies (knowledge transfer).

4.1.2.4 Approach to explain the mentioned IS phenomena

Phenomenon 1: Systems can have external connections of differing strengths. With respect to enterprises and their departments, they are usually relatively strong and cannot simply be omitted by idealization.

Phenomenon 2: If you draw system boundaries which are too narrow and too hard, you lose essential connections. This is true for every kind of punctual solution, for isolated solutions as well as for the following.

Example: In order to reduce the capital tied up in the raw materials inventory, an IS expert supports the purchase department by IT, but does not realize that both the purchase department and the production department order raw materials. That means that the problem is somewhere else, but it can not be figured out because the system boundaries are defined too narrowly.

4.1.2.5 Proposal for solution

It is true that the problem of isolation is fundamentally unsolvable, but there are methods to cope better with it. An accurate pre-analysis of the object domain has to be done with a well-reasoned system limitation, before starting the formal modeling itself.

The first step is to explicitly figure out the system purpose, that is: It has to be settled clearly from what points of view a system as descriptive category has to be delimited and to be regarded: Which questions it should answer, which purpose it should meet and for what objectives (for what optimizations) it should be used.

The following rule of thumb is well verified by experience: Avoid hard system boundaries, but mark a soft, blending rim, as if you were to look thru a magnifying glass with the strongest magnification (highest precision) in the middle and continuously decreasing magnification (reduced precision) as you move out towards the rim. With increasing diameter, the precision decreases in concentric rings around the suspected core problem.

If you are not willing to make this effort you should at least comprehensively include system surroundings and external connections as SA level 0 (context) diagrams already suggest. It is urgently recommended to the computer scientist to mark the system boundaries wider than the ones of the immediately relevant IT domain.

4.2 What are the particularities of the IS objects of cognition with respect to formalization? Inhomogeneity, heteronomy; pre-formalization, suitability for formalization; compatibility of IT tool and IT application field

4.2.1 What are the particularities of the IS objects of cognition? Inhomogeneous, autonomous-heteronomous object domains; 'human factor', communication as basis for observation

4.2.1.1 Phenomena

1. Why is the belief in all-encompassing IT solutions misleading?

2. Why does the installation of IT infrastructure (for example electronic mail) not necessarily imply its profitable use by the end user?

4.2.1.2 Explanation by critical realism

Enterprises with all their various phenomena are objects of cognition/observation, just as object domains of nature which are observed in physics. In contrast to the self-constituted natural object domains, the IS object domains are heterogeneous combinations of

1. internally constituted (autonomous, endogeneous) natural parts, that is, the humans involved (the so-called 'human factor'), whom the IS expert tends to ignore because they cannot be formalized.
2. externally constituted (heteronomous, exogeneous) artificial parts, the organization and process structures involved in an enterprise, which the IS expert above all has in his view. They are pre-formally structured and therefore reduce the problem of isomorphy (4.2.2). These parts are created and formed by humans in order to guarantee survival and to organize human society (3.1.2.3).

4.2.1.3 Explanation by evolutionary epistemology

Human knowledge acquisition has its starting point in simple, homogeneous items of everyday life (4.1.2). But the bigger and more complex an object domain is, the less probable its homogeneity becomes.

4.2.1.4 Approach to explain the mentioned IS phenomena

Phenomenon 1: There are no all-encompassing IT solutions, as the IS object domains can only partly be registered by formal description. This is because they cannot be completely formalized. Reasons:

1. The very problem of isomorphy (4.1.1) is fundamental and therefore grave and severe.
2. The autonomous parts aggravate this problem considerably, as humans can scarcely be pressed into the rigid framework of formal models.

Phenomenon 2: As humans cannot be formalized, blind IT application ignores the operating end users' human nature: An exclusively formal optimization is of no use against psychological blocks (for example information is a personal possession and gives power; computers are rejected; there is fear of losing one's job; new techniques cause fear etc.).

4.2.1.5 Proposal for solution

There is no fundamental solution to the human factor problem. To replace *data processing* by *information technology* only changes labels, but not the situation. An IS expert should not be an advocate of new terminology, but he should be aware that humans determine information handling processes on a large scale; and humans are not suitable for formalization. Hence, he has to use all means to implement the following two strategies:

1. The introduction of participative strategies leads to a considerable extenuation of the situation. That is, the early and complete involvement of the IT-applying enterprise with the later end users, in combination with fair information about all the relevant connections.
2. As I already indicated with my IS interpretation (1.2), non-formal optimizations are necessary in addition to formal IT-based ones. In order to inspect the potential and necessity of optimization, an exhaustive organizational consultation has to take place. It should encompass:

2.1 Possibilities for non-formal optimization (for example the psychological situation of the employees: IT acceptance, IT estimation, IT expectation, IT fear, group dynamics, human resources psychology, organizational and motivational psychology).

2.2 Possibilities for formal optimization without IT (for example card indexes).

2.3 Possibilities for formal optimization with IT.

In my opinion, this extension of IS is urgently necessary. Thus, IS has the chance to further develop into a real information science.

4.2.1.6 Remark

In the following considerations of 4.2, I confine myself to the heteronomous parts, as the autonomous ones had just been discussed in detail in 4.2.1.

4.2.2 How can IS objects of cognition be discriminated with respect to formalization? Different degrees of pre-formalization, suitability for formalization and effort (difficulty) of formalization

4.2.2.1 Phenomena

1. Why is it more difficult to model small enterprises than large ones?
2. Why is it easier to develop and introduce software for the accounting than for the production?
3. Why do CIM concepts not lead to the desired success?
4. Why do expert systems not lead to the desired success?

4.2.2.2 Explanation by critical realism

With respect to formalization, there are three dimensions where the IS object domains (and the object domains of empirical sciences in general) can be distinguished:

1. Pre-formalization (preliminary formalization)
2. Suitability for formalization
3. Effort (costs, difficulty) of formalization

Not every object domain is pre-formalized up to the same degree and can be modeled formally and causes the same effort of formalization: There are (without sharp boundaries, of course):

1. Scarcely pre-formalized object domains are not based on a formal model (for example certain kinds of production; humans; natural language, machine translation). Their formalization is time-consuming and difficult They cause a considerable effort of formalization. They can never be completely formalized (4.2.1, human factor) and their partial formalization need not be crowned with success at all.

2. and 3. Object domains which are based on a formal model, as such a model was already included in their constitution. They have to be distinguished according to the degree of awareness of the model:

2. Object domains with little pre-formalization are based on an implicit formal model. The employees are scarcely aware of using a formal model; the corresponding terminology is scarcely established. Object domains of this kind can often be formalized quite well, but with an increased effort of formalization (for example small and medium enterprises, see below 4.2.2.5). It can often be found out that standard cases cause relatively little effort of formalization, special cases however a multiple one.

3. Well pre-formalized object domains are based on a formal model, which is highly explicit. The employees consciously use the formal model, the corresponding terminology is well established (for example accounting). Object domains of this kind can be formally modeled with extremely little effort and present themselves as a starting point for the IT introduction in an enterprise (4.2.1).

4.2.2.3 Explanation by evolutionary epistemology

Starting from the optical-tangible physical items in everyday life (4.1.2), the uniformity and homogeneity of various object domains is assumed. This ínevitably leads to fallacies in case of more complex ones. In the same way, an exclusion of overlaps is assumed as if world 1 consisted of building blocks. This is not correct in case of functional objects (see 4.2.2.4, phenomenon 1). Optical-tangible objects and functional objects need not coincide and correspond to each other.

4.2.2.4 Approach to explain the mentioned IS phenomena

Phenomenon 1: In small enterprises, many tasks are done in personal union. The task structure (functional objects) is much finer than the personnel structure (optical-tangible objects, 4.1.2), for example the functions 'boss, sales representative and buying agent' can be exercised by one and the same person.

Phenomenon 2: Accounting is a pre-formalized enterprise domain, whereas individual information handling processes in production are often not suitable for formalization.

Phenomenon 3: Naive CIM advocates start from the (implicit) wrong axiom that different enterprise domains would be suitable for formalization in the same degree.

Phenomenon 4: Naive expert systems advocates start from the wrong axiom that all fields of human thinking would be suitable for formalization in the same degree as human arithmetical abilities.

4.2.2.5 Proposal for solution

It is necessary that a SW developer is familiar with the different properties of object domains. The user has to be informed about these connections.

During the analysis of the current state (4.2.3), a concrete object domain has to be inspected with respect to its pre-formalization and its suitability for formalization (2.3.2). From the thus gained results, the following conclusions have to be drawn:

1. The time management for the formal modeling has to be planned in consideration of the expected amount of effort necessary for formalization.
2. Enterprise domains which are well suitable for formalization, present themselves as starting points for the IT introduction in an enterprise. In a producing enterprise, the sequence of introducing IT could thus be: accounting, order management, materials management, production.
3. Formalizations must not be forced at any rate. In case of difficulties in formalization, it is necessary to allow fuzzy decisions (chaotic oscillations) within a certain range. Example: A hammer is required for an activity, but not a definite specimen.

4.2.2.6 Remark

My considerations above on formalization can similarly be applied to pre-structuring (preliminary structuring) and suitability for structuring in the sense of decomposability (4.1.2) and to pre-mathematization (preliminary mathematization) and suitability for mathematization (2.3.4). The essential requirement of mathematical correctness, the consistency, needs not at all be met in every enterprise (3.1.1.2).

4.2.3 What is the purpose of the formal optimization of business processes? Compatibility of tool and application field, principle of key and lock

4.2.3.1 Phenomena

1. Why is the effect of exclusive IT application still overestimated?
2. Why does software often not fit a complex enterprise domain as desired, even if the concept was modeled thoroughly?

4.2.3.2 Explanation by critical realism

An IT tool (straight key) is formal and therefore only fits a formal application field (straight lock). Therefore, IT is not a remedy against disastrous organization (crooked lock) and it cannot support high-grade spontaneous information handling processes in the same way that a straight key cannot be put in a crooked lock.

4.2.3.3 Explanation by evolutionary epistemology

It is obvious from human evolution that tools normally have to be adapted to their application fields. In contrast to all our habits, the opposite procedure is additionally required within computer science: Computer science tools only fit application fields which have been formalized. This formalization may have to be performed.

4.2.3.4 Approach to explain the mentioned IS phenomena

Phenomenon 1: It is not common knowledge that IT applications require business process reengineering (that is, formalization of the application field).

Phenomenon 2: If this fact is ignored the user makes the wrong claim that IT should be a remedy against disastrous organization, and every SW concept is worthless.

4.2.3.5 Proposals for solution

Before formally modeling the key, it is necessary to formalize (straighten) the lock (business process reengineering). This fact induces the following interpretation of the classical partial phases (subphases) of the systems analysis phase:

Survey of the current/actual state: Scientific description and modeling of the lock.

Analysis of the current state: Is the lock pre-formalized (straight) or not (crooked)?
- Can the lock be formalized (straightened)?
- How and up to which degree can the lock be formalized?

Concept of the planned state: Formal model of the lock.
- Formal model of the key.

4.2.3.6 Remark

There are further phenomena which belong to 4.2. They have their origin in the incomplete observability (statistical analysis in management information systems) and the temporal dynamics of object domains. To discuss them here would be beyond the scope of this contribution.

4.2.4 How is the temporal behavior of world segments? Dynamic models

[under construction]

4.3 How do subjects of cognition treat objects of cognition? Particularities of human thinking during model construction

4.3.1 How do humans think generally, how should they think? Essential properties of human thinking

4.3.1.1 How can human cognitive processes be temporally linearized and structured? Iterative phase concepts, levels of design

4.3.1.1.1 Phenomena

1. Why do phase concepts not lead to the desired success?
2. Why are there so many different phase concepts?
3. Why are top-down and bottom-up approaches not executed consequently?
4. Why do data modeling and static object modeling more often lead to uniform results than function and (business) process modeling?

4.3.1.1.2 Explanation by critical realism

Every temporal decomposition produces critical cases. With regard to a certain concrete particular activity, it may not at all be evident to which partial phase of a strictly serial phase concept it belongs.

4.3.1.1.3 Explanation by evolutionary epistemology

1. Multi-dimensional thinking is an advantage for survival. Humans always regard several decision levels at the same time, temporally parallel and not in sequence. Therefore, it is difficult to linearize mental cognitive processes.
2. As the human cerebral cortex has an optical-tangible orientiation (4.1.2), humans are much better ‘prepared’ to decompose (structure) spatial continuous domains than temporal ones. It is difficult to apply spatially determined decomposition (structuring) strategies to temporal, continuous domains.

4.3.1.1.4 Approach to explain the mentioned IS phenomena

All procedure models (phase concepts) are standard rules which do not include the reflection of cognitive processes. They are partly very miserable attempts to structure modeling processes.

Phenomenon 1: It is difficult to separate survey of the actual state, analysis of the actual state and concept of the planned state. A survey of the actual state is not possible without valuation (analysis of the actual state). An analysis of the actual state is not possible without viewing the favorite alternative solution (concept of the planned state). A concept of the planned state is not possible without viewing the implementation.

Phenomenon 2: It is impossible to figure out exact laws to define partial phases and their further decomposition. That is why there are no boundaries for human creativity.

Phenomenon 3: A top-down analysis without simultaneous bottom-up analysis can not succeed because – according to experience – an abstraction level always has to be modeled starting from both sides, from the immediately higher and the immediately lower level.

Phenomenon 4: Data models and static object models correspond to spatial structures. Via normalization, it is possible to arrive at results which are highly independent of personal interpretations and which are temporally quite stable. Function and process models correspond to temporal structures. They depend a lot on the subject of cognition (model designing subject) and are temporally quite unstable. The reason for the different temporal behavior of the two structures is that data structures in enterprises are temporally much more stable than process structures; the latter is a consequence of the optical-tangible determination of thought.

4.3.1.1.5 Proposal for solution

1. It is impossible to avoid a certain temporal structuring, especially with respect to big projects with lots of developers.
   For this purpose, iterative (maieutic cycles, 2.2.5), flexible phase concepts which can be adapted to the particularities of a project in a differentiated way, are required. Phase concepts do not exist for their own sake. They should support projects and not be verified by projects. Unreflected obedience to standard rules is detrimental. A self-critical orientation to standard rules is advantageous when based on a profound knowledge of cognitive processes.
2. At least with respect to smaller projects, I have had very good experience with the following procedure: A project team is allowed to model several given design/abstraction/decision levels simultaneously. These levels can be adapted to the project's particularities if necessary. The team can use its time in a very flexible way. The particular design decisions have to be assigned to the decision levels on the basis of a good motivation. This means that the temporal structure (design phases) is replaced by a spatial structure (design levels).
3. When modeling enterprises, the starting point should always be the easiest and least subjective approach, that is, the normalized data modeling or static object modeling. It produces quite stable results, whereas function/process models can reflect very subjective opinions when regarded from different points of view.

4.3.1.1.6 Remark

Further phenomena, such as the human problems under formalization, mathematization and treatment of critical cases, can not be explained in detail at this time. I must equally omit a discussion of the creativity of human thought in the inductive inspiration which cannot even be replaced by the best modeling tools.

4.3.1.2 Why is process decomposition more difficult than data decomposition? Laws of gestalt psychology

[under construction]

4.3.1.3 Why do humans have difficulties with formalization, mathematization etc.? These skills are not primarily necessary for survival

[under construction]

4.3.2 What circumstances exert an influence on individual human thinking? Accidential properties of human thinking depending on disposition

4.3.2.1 Why are models of different subjects of cognition not necessarily correct and consistent? Psychic-intellectual-social disposition of subjects of cognition

4.3.2.1.1 Phenomena

1. IT experts – experienced in a particular trade – analyse an enterprise which is little formalized and very individually managed. Why do some of them try to put it into the schemas of standard cases, to describe it with their descriptive categories so that the enterprise's individuality can be lost during model construction?

2. In contrast: IT experts without knowledge of the particular trade and without much general experience are in the same situation. Why do some of them not detect standards which are valid for many enterprises?

4.3.2.1.2 Explanation by critical realism

There is no knowledge without any subject of cognition, no science without any scientists, no model without any model designers. Therefore, properties of the subject of cognition always play a role in knowledge acquisition.

The model designer's mental processes (and therefore the model construction itself) are influenced by his (un)conscious (pre)disposition (state of mind), in particular:

1. psychologically: by his unconscious attitudes, his fear and (self-)confidence, his emotional relation to the modeling object.
2. intellectually: by his conscious attitudes, his higher education, his foreknowledge and his prejudices, his experiences, his lack of knowledge, his world 3 activations, his fundamental epistemological point of view, his knowledge about priciples of modeling, his estimation of the effort of modeling;
3. socially: by his environment with respect to human resources psychology, his team qualification, his time pressure.

4.3.2.1.3 Explanation by evolutionary epistemology

Humans react on known and standard cases in an analogical and conservative way according to standard strategies, in a spontaneous, creative and progressive way on unknown and critical cases. This flexible mode of reaction guarantees advantages for survival. With respect to my modeling method in 4.1.1, the part of the reference model reflects the analogical thinking, the part of the individual model the spontaneous one.

The degree of familiarity with a phenomenon, however, is not an objective, but a subjective category. Due to his different dispositions, one human can react conservatively in a given situation, another one progressively, in one and the same situation. This is the reason why different model designers attach different importance to the two parts of modeling.

Humans primarily estimate their cognitive processes in a naive-realistic way (regardless of their personal disposition). They are not aware of being involved subjectively and personally. The lack of knowledge about the connections mentioned leads to an insufficient modeling method.

4.3.2.1.4 Approach to explain the mentioned IS phenomena

Phenomenon 1: When experienced in a trade, a model designer often is too sure (confident) of his territory and tends to emphasize reference models and to neglect the particularities of an enterprise. He tries to press every enterprise into the standard of its trade. The danger of a hermeneutic circle arises. That is the danger that he puts the same knowledge into the analysis which he gets afterwards as a result.

Phenomenon 2: If the model designer does not have an analogical starting basis (for example due to his lack of knowledge) he must react in a spontaneous, flexible and creative way. This is the reason for neglecting the part of the reference model in this case.

4.3.2.1.5 Proposal for solution

The illusion of the observer's neutrality has to be dropped, for it is fundamentally impossible to exclude the influence of diverse dispositions of a model designer. When they are dealt with in a conscious and highly reflected way, the worst consequences can be avoided. That is why every IS/CS expert should have a sharpened (keen) awareness of the constraints of observation and modeling processes which depend on the individual subject. The same rule applies to all epistemological constraints and their consequences for the modeling method. It is therefore important to teach knowledge of this kind within a computer science study program. The congress topic 'IS and theory of science' should become a focal point in software engineering and IS courses. (By the way, this includes the training of model representation skills as well.)

4.3.2.2 Why are humans not fond of model description? Concentration on primary results

[under construction]

4.4 How do subject of cognition and object of cognition interact? Observer as part of the observed object domain, missing self-containment (closure) of objects of cognition: interdependency instead of independency

On the one hand, humans (world 2) know descriptive frameworks and categories for world 1 which are given in world 3. They can also construct additional ones from the existing potential. Humans thus influence the interpretation of their observation results (4.1.1). On the other hand, humans can exert an immediate impact on observation objects (objects of cognition):

4.4.1 Phenomena

1. The analysis of the actual state is completed for only a little formalized enterprise domain. Why do – just in this case – a lot of checking questions subsequently arise so that you had better wait a little until you start to implement or to customize a software system?
2. Why does an external analysis of information handling processes in enterprises sometimes lead to unrealistic results?

4.4.2 Explanation by the critical realism

On the one hand, the cognition of objects of cognition requires the constitution of subjects of cognition. If there were no subject-object-separation humans could not delimit themselves from world 1 and produce self-consciousness. Vice-versa, the rigor of the separation leads to incorrect knowledge in many fields. (I could have formulated this paradox as third epistemological dilemma in 4.1 as well.)

On the other hand, human cognitive power determines the objects of cognition (4.1.1). From this point of view, there is a mutual existential foundation: There are no subjects of cognition without objects of cognition and vice-versa.

When observing, the observer (subject of cognition) becomes a part of the object of cognition which he observes (3.3.3). He has to extend the object of cognition by himself and thus define a new, bigger object of cognition. The subject-object-boundary becomes more or less indistinct and there is mutual influence:

1. The observer acts on and changes the object of cognition.
   Objects of cognition are influenced and changed by active, 'unconcealed' observation which the observed object of cognition can notice.
2. Vice-versa: The process of observation retro-acts on the observer.
   Observation frameworks and modeling concepts in world 3 can change during the course of time. The observer extends his knowledge during observation and its interpretation. He changes his world 3 activations: After being observed for some time an enterprise presents itself in a new aspect. By feed-back, the changed world 3 retro-acts on the observer's perception and interpretation of world 1 (3.1.3).

4.4.3 Explanation by evolutionary epistemology

The subject-object-separated view of cognition is determined by the primary objects of cognition, that is, optical-tangible physical items. Subjects have to delimit themselves from such items. In this case, the subject-object-separation makes sense and is absolutely inevitable for evolution in order to constitute a self-conscious subject. The Ego arises between It and the world, as Freud says. This naive-realistic thinking fails, however, in the case of objects of cognition in the physical microcosmos and in the social world.

4.4.4 Approach to explain the mentioned IS phenomena

Phenomenon 1: An enterprise is a social structure which is changed by observation, just like a sub-atomic particle. One consequence of the interviews by a consultant or systems analyst is that considerable internal formalization and optimization processes can be initiated. The users' attitude towards (new) IT can be influenced as well. The effects of an analysis of the actual state often only gradually become obvious if the users do not have any possibility to report their new ideas.

Phenomenon 2: An external analyst often has to face the employees' fear of losing their jobs due to rationalization. If it is not possible to establish personal confidence in him, some employees will always veil or even withhold information.

4.4.5 Proposal for solution

1. It is necessary to plan a long period of observation in order to give the observed, analyzed enterprise and its observer time to get used to the observation situation and to stabilize the observation results. The maieutic cycles (2.2.5) have to be largely extended. Post-analysis sessions have to be planned.
2. You have to expect changes in the behavior of the future users (acceptance, refusal of IT application). Participative strategies can give information about their current attitudes and will contribute to better personal confidence between systems analyst and employees.

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