Business Informatics: Research Methods

Christian Huemer
with Slides from Hannes Werthner

Based on Bakos, Brynjolfsson, Buchberger, Fitzpatrick, Hevner, Giunchiglia, Kappel, Kellner, Klein, Kroich, Pobiedina, Ricci, and some other (unknown) authors

Seminar for Master Students @ TU Vienna

Business Informatics Research that matters!

With slides from H. Werthner, G. Kappel (TU Vienna)

by Christian Huemer @ IEEE CEC 2012, Hangzhou

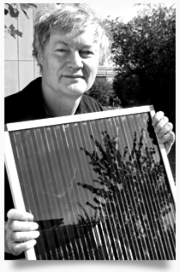
AWARDING
EXCELLENCE
SINCE 2002

MILLENNIUM
TECHNOLOGY
PRIZE

2010

DYE-SENSITIZED SOLAR CELLS

INNOVATION
APPLICATIONS



MICHAEL GRÄTZEL

Professor, Director of the Laboratory of Photonics and Interfaces, Ecole Polytechnique Fédérale de Lausanne (EPFL)

Switzerland

2008

CONTROLLED DRUG RELEASE

INNOVATION
APPLICATIONS
WINNER

ROBERT LANGER

Professor

2012

OPEN SOURCE OPERATING SYSTEM

INNOVATION
VIDEO

LINUS TORVALDS

Finland / USA

ETHICAL STEM CELLS RESEARCH

INNOVATION
VIDEO

SHINYA YAMANAKA

Professor

Japan

2014

Increased data storage density

Stuart Parkin

2006

BLUE AND WHITE LEDS

INNOVATION
APPLICATIONS
WINNER

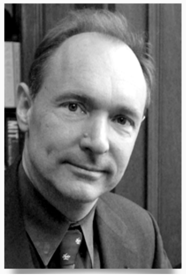
SHUJI NAKAMURA

Professor

2004

WORLD WIDE WEB

INNOVATION
APPLICATIONS
WINNER



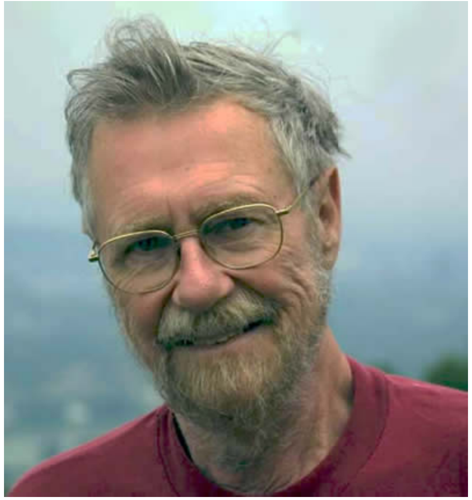
TIM BERNERS-LEE

Professor

Computer Science

Edsger W. Dijkstra:

The job [of operating or using a computer] was actually beyond the electronic technology of the day, and, as a result, the question of how to get and keep the physical equipment more or less in working condition became in the early days the all-overriding concern. As a result, the topic became —primarily in the USA— prematurely known as "computer science" —which, actually is like referring to surgery as "knife science"— and it was firmly implanted in people's minds that computing science is about machines and their peripheral equipment. Quod non [Latin: "Which is not true"].



Informatics

Kristen Nygaard:

Informatics is the science that has as its domain information processes and related phenomena in artifacts, society and nature

Informatics

Kristen Nygaard:

Informatics should be defined like most other sciences (and unlike mathematics) as:

The study by scientific methods of a domain of phenomena and a perspective selecting a set of characteristics of those phenomena

That is, like physics, chemistry, botany, sociology, political science

Three traditions in informatics

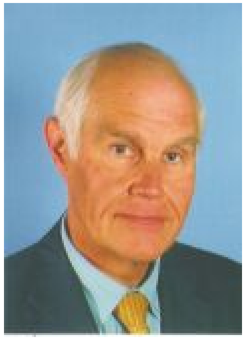
- The Sciences
  - Scientific calculations. Algorithms. Languages. Correctness. Provability.
  - Emerging from Departments of Mathematics
- Construction
  - Digital electronics. Engineering calculations. Packages. Case tools. Software engineering.
  - Emerging from Departments of engineering.
- Administration
  - Accounting. Databases. Management information systems. Organisation. Decision support.
  - Emerging from Schools of business administration

Information Systems

The field of information systems targets the development of IT-based services, the management of IT resources, and the use, impact, and economics of IT with managerial, organizational, and societal implications.

Information Systems (Germany)

- Definition by Mertens et al.
  - Information Systems deals with *design, development, deployment, maintenance, and deployment* of systems for computer supported data processing in organizations



- Definition by Scheer
  - Information Systems is the *science* on *design, development and deployment* of computer supported information systems for business administration

- Definition by the WKWI
  - The goal of Information Systems is the production of *theories, methodologies, tools and inter-subjectively verifiable knowledge* on information and communication systems (…) as well as the *explanations and forecast of the behavior* of such systems - and *the design of novel systems*

German Memorandum

- Österle et al:
- The most prominent objective of European IS research has basically been to produce practically beneficial, business relevant results. Adoption of these results by business (i.e., economic payoff) has often been considered more important in terms of providing evidence of the correctness of results than transparent, well-documented scientific development of results following generally accepted criteria (i.e., scientific rigor).

Research Methods

Understand how things are (natural/behavioral)

Develop **theories**

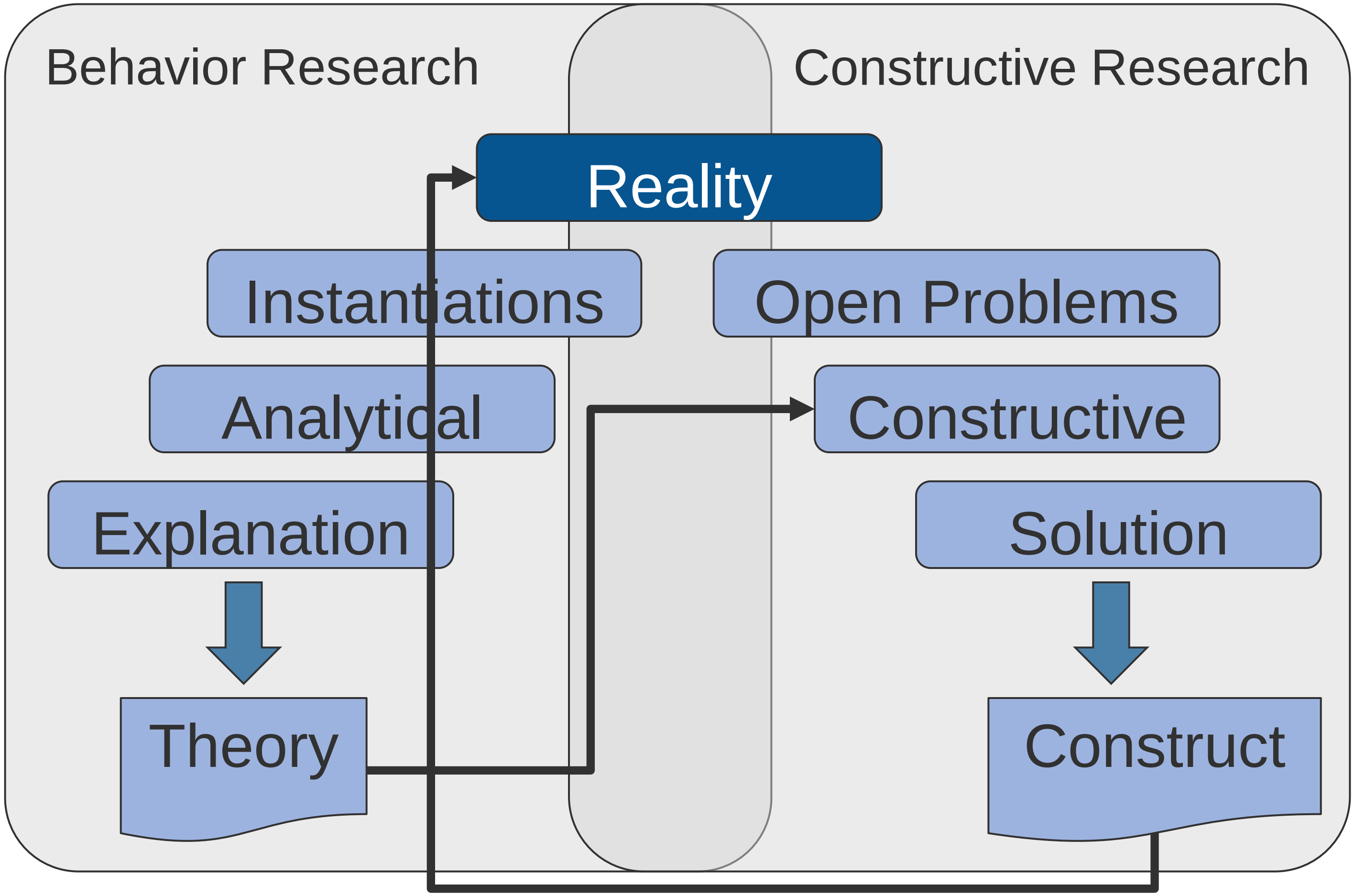
Justify using
- data collection
- experimentation
- field study
- case study
- quantitative/qualitative analysis

Change things as they are by creation (design science)

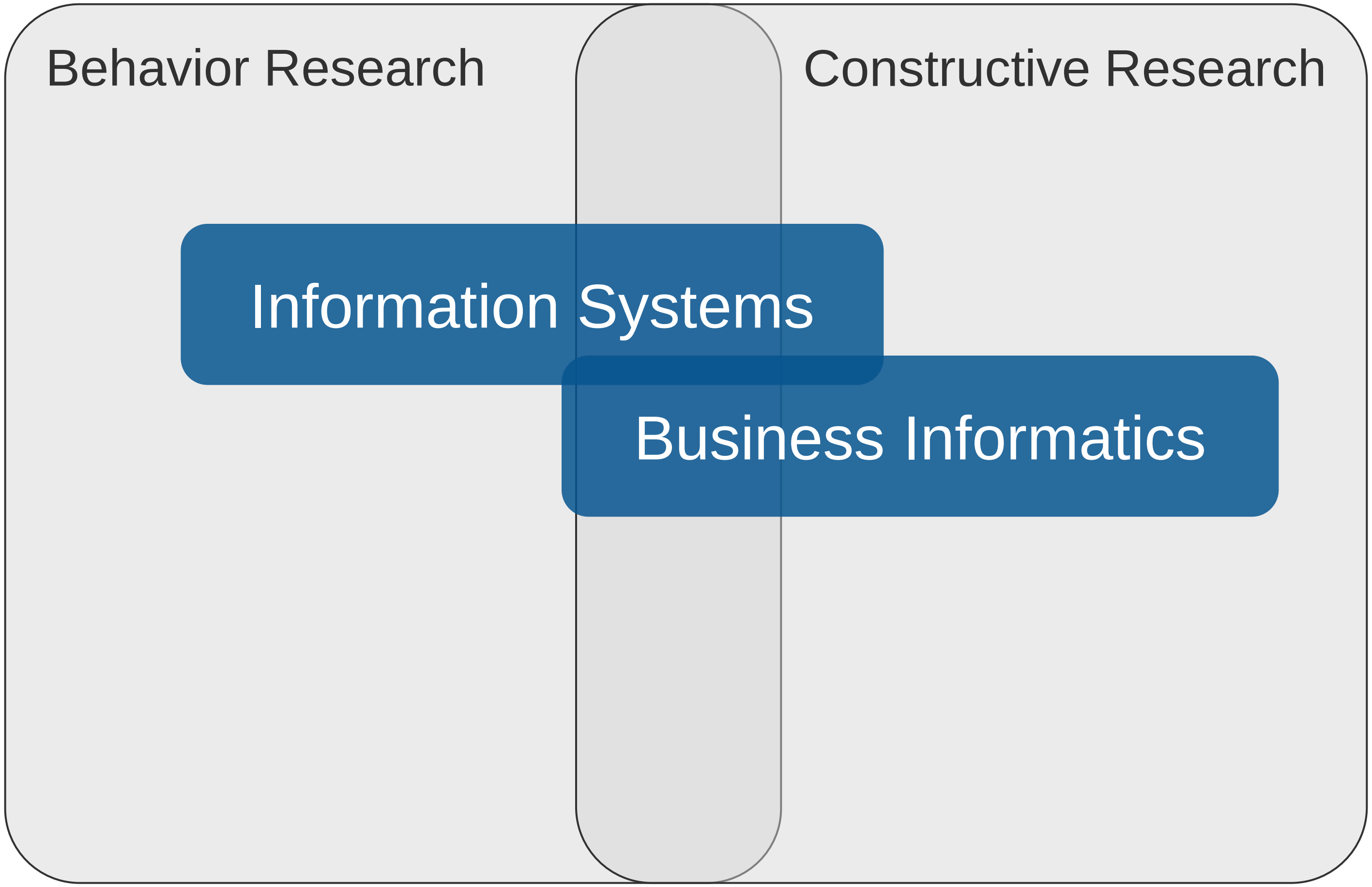
Build **artifacts**

Evaluate using
- Analytical
- Simulation
- Instantiation
- experimentation

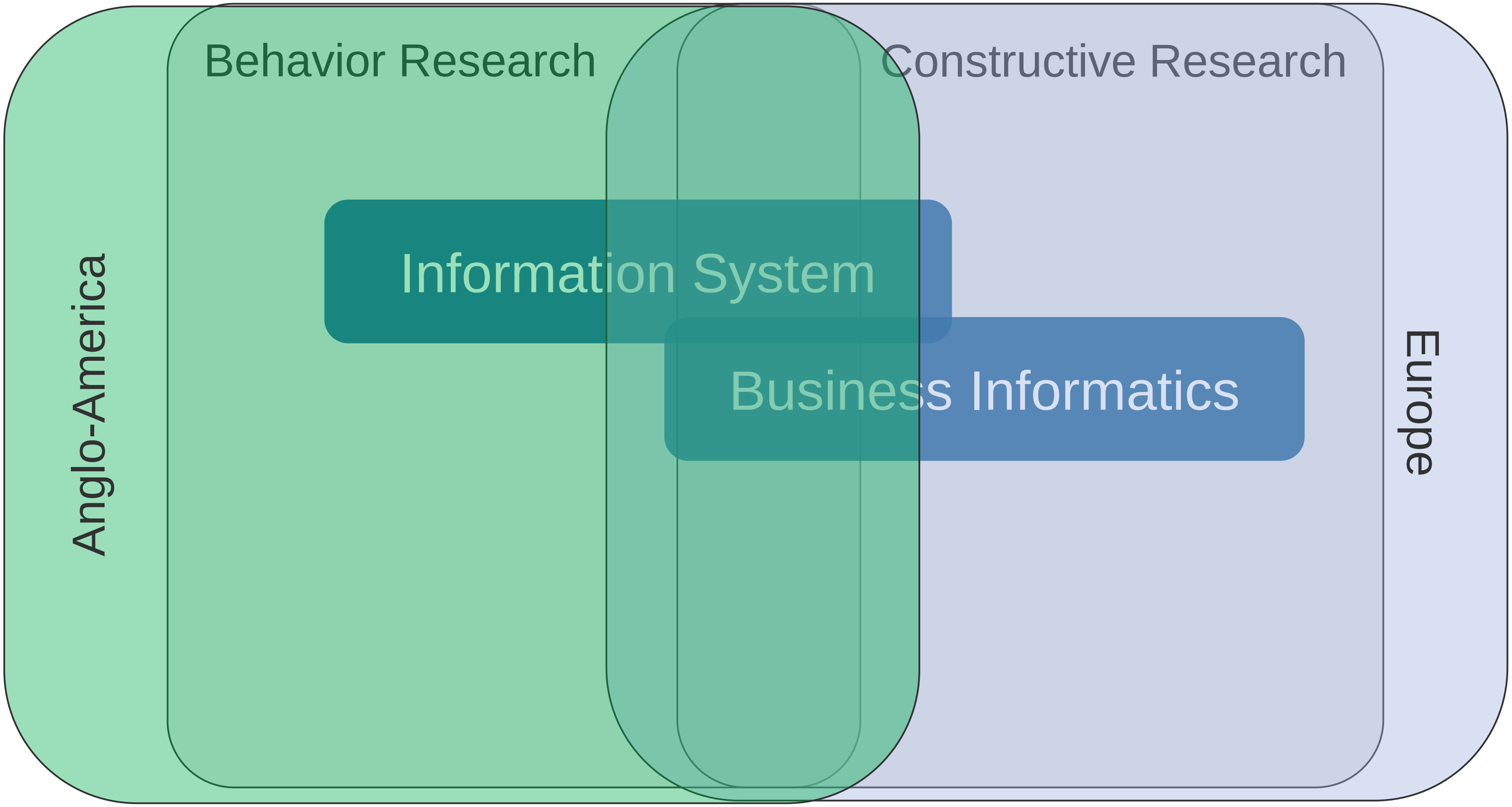
Research approaches



Research approaches



USA – Europe


Behavior Research
Constructive Research
Anglo-America
Information System
Business Informatics
Europe

Business Informatics at TU Wien

Curriculum 2011

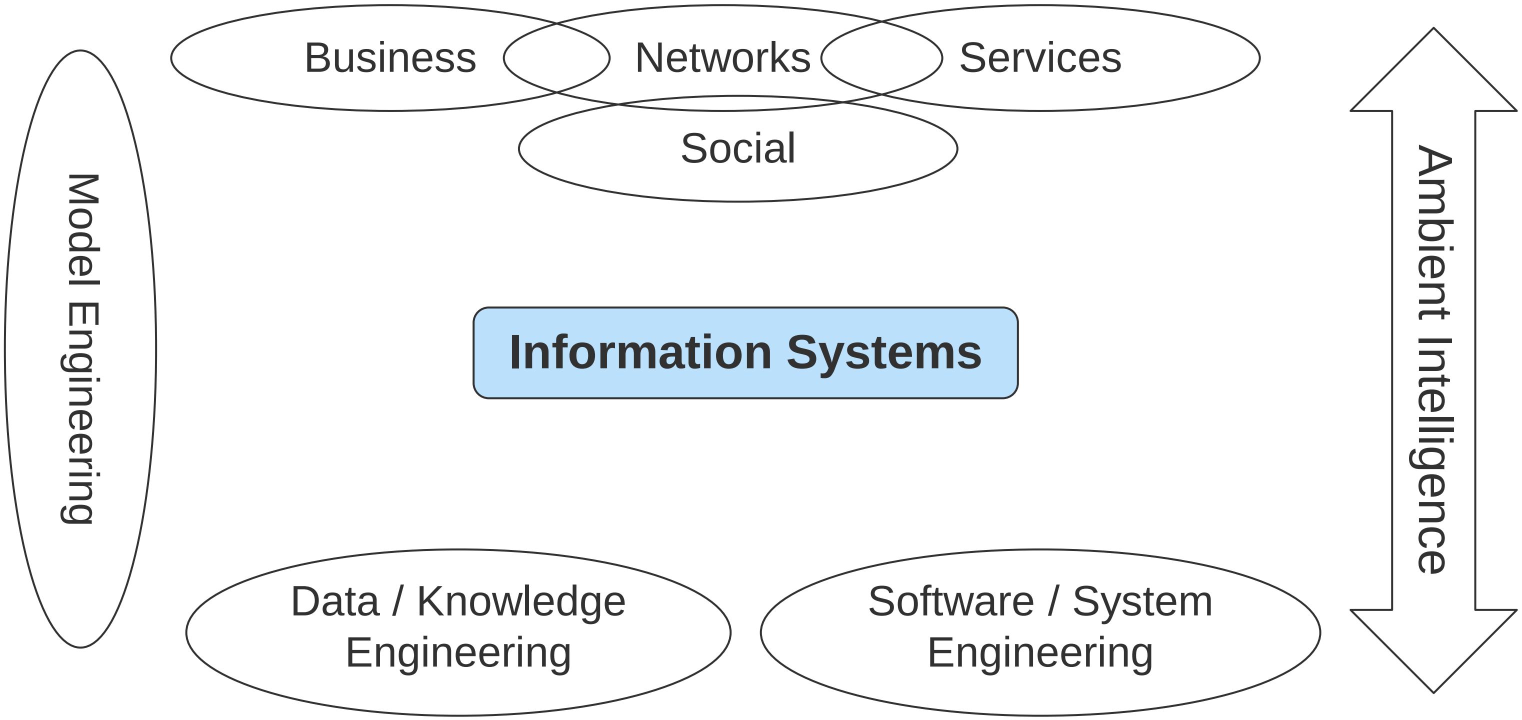
Business Informatics covers information and knowledge as well as *information related processes* in organizations and society

Looks at interface between *humans*, *organizations*, and *information technology*

Objects are information and communication systems in economics and society, especially the *analysis*, *modeling*, *design*, *implementation*, and *evaluation* of such systems

Besides the primarily computer science-oriented approach, the success of such systems requires the consideration of *technical*, *economic*, and *social* aspects

Business Informatics at the Vienna University of Technology



Based on [5]

Science

- Acquisition of reliable but not infallible knowledge of the *world*, including explanation of the phenomena
- Science is based on what is *observable* in the universe
- For something being subject of scientific research it must be *measurable*
- *Tasks of science:*
  - *Describe:* precondition for other tasks. Result is a model (systematic model - documentation of reality)
  - *Explain:* explanation of relationship between objects and their dependencies
  - *Predict:* statements able to explain phenomena can also be used to predict. Applying a general theory plus specific boundary conditions one can predict future events
  - ***Construct****:* constructing artefacts (such as in Computer Science), or giving economic (political) advice, or advice for companies (management science)

Research

- “Research can be very generally defined as an activity that contributes to the understanding of a phenomenon.” [Kuhn, 1996; Lakatos, 1978]
- Research is to provide a method for obtaining answers to questions asked

- Basic research
  - Search for knowledge of properties of objects, their relationship and their behavior
- **Applied research**
  - Search for solutions to practical problems using this knowledge
  - Usefulness of objects and their behavior, may lead to improved technology

Research approaches

- Logics / math (deduce and reason)
  - Formal reasoning approach
- **Engineering (construct, design)**
  - Attempts to create things that serve human purposes
  - Design is both a process and a product
  - Problem-solving paradigm
- Natural science (observe, analyse, predict)
  - “Traditional” research in physical, biological, social, and behavioral domains
  - Specifies concepts and languages to characterize phenomena
  - Emphasizes evidence, especially as discovered in experiments

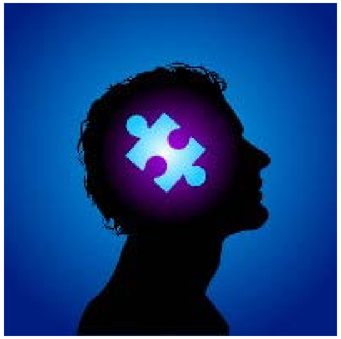
Methods

- Play central role, the way how scientific knowledge is gained

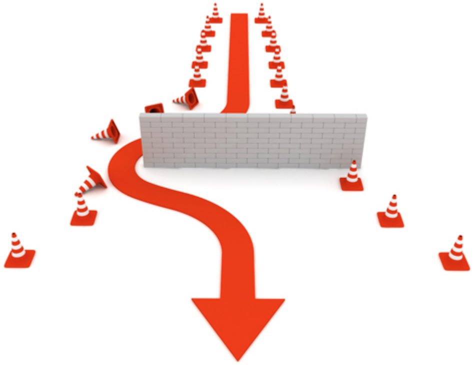
- “methodos” means way
- Methodology is the discipline of scientific procedures
- Proper application “leads” to results

What counts more …

the research result



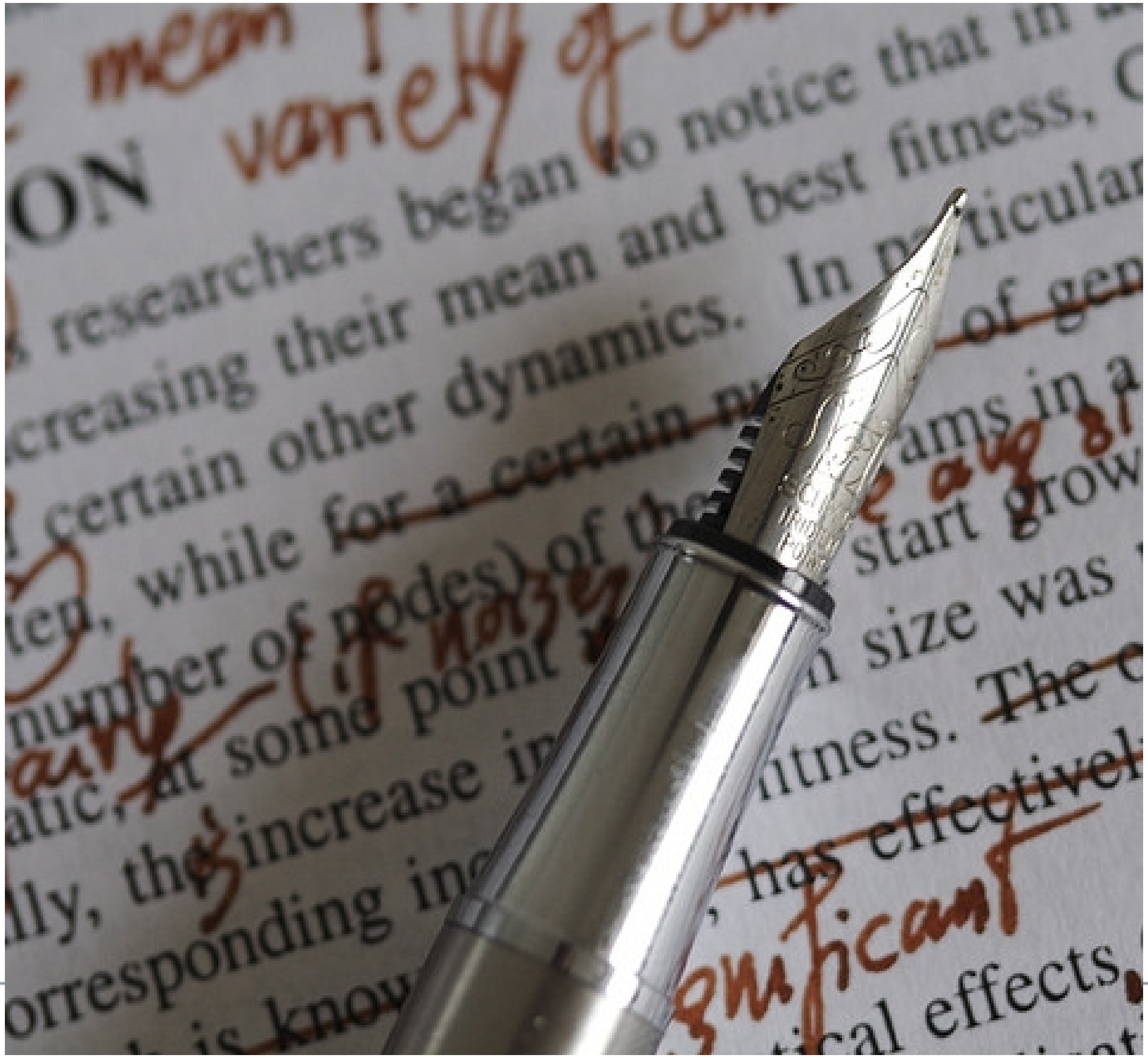
or



scientific rigor?

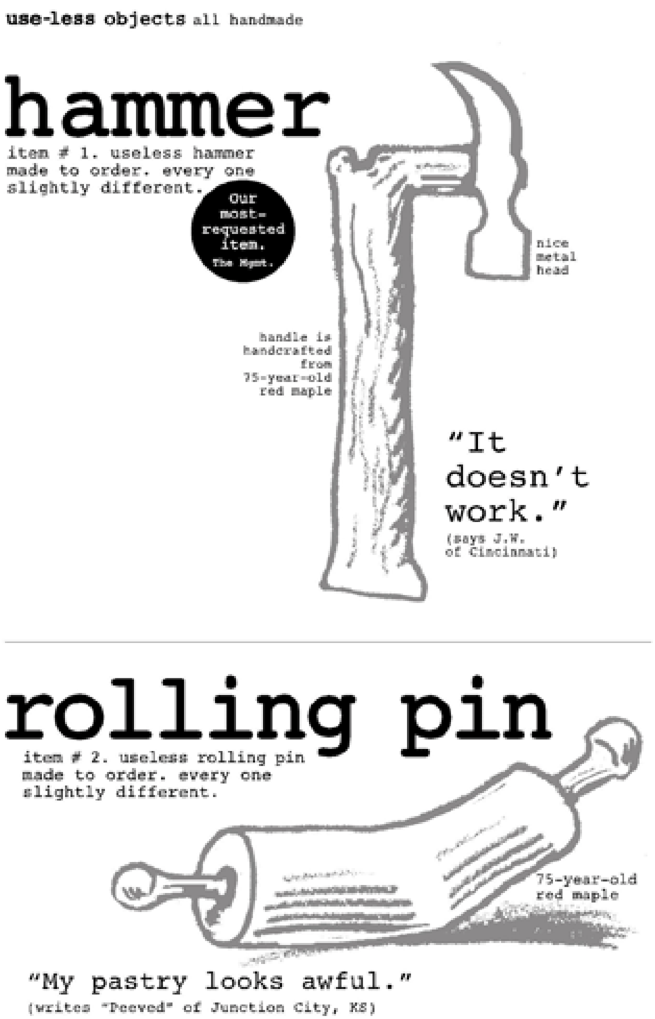
Consulting is not research

Soundness



Business Context

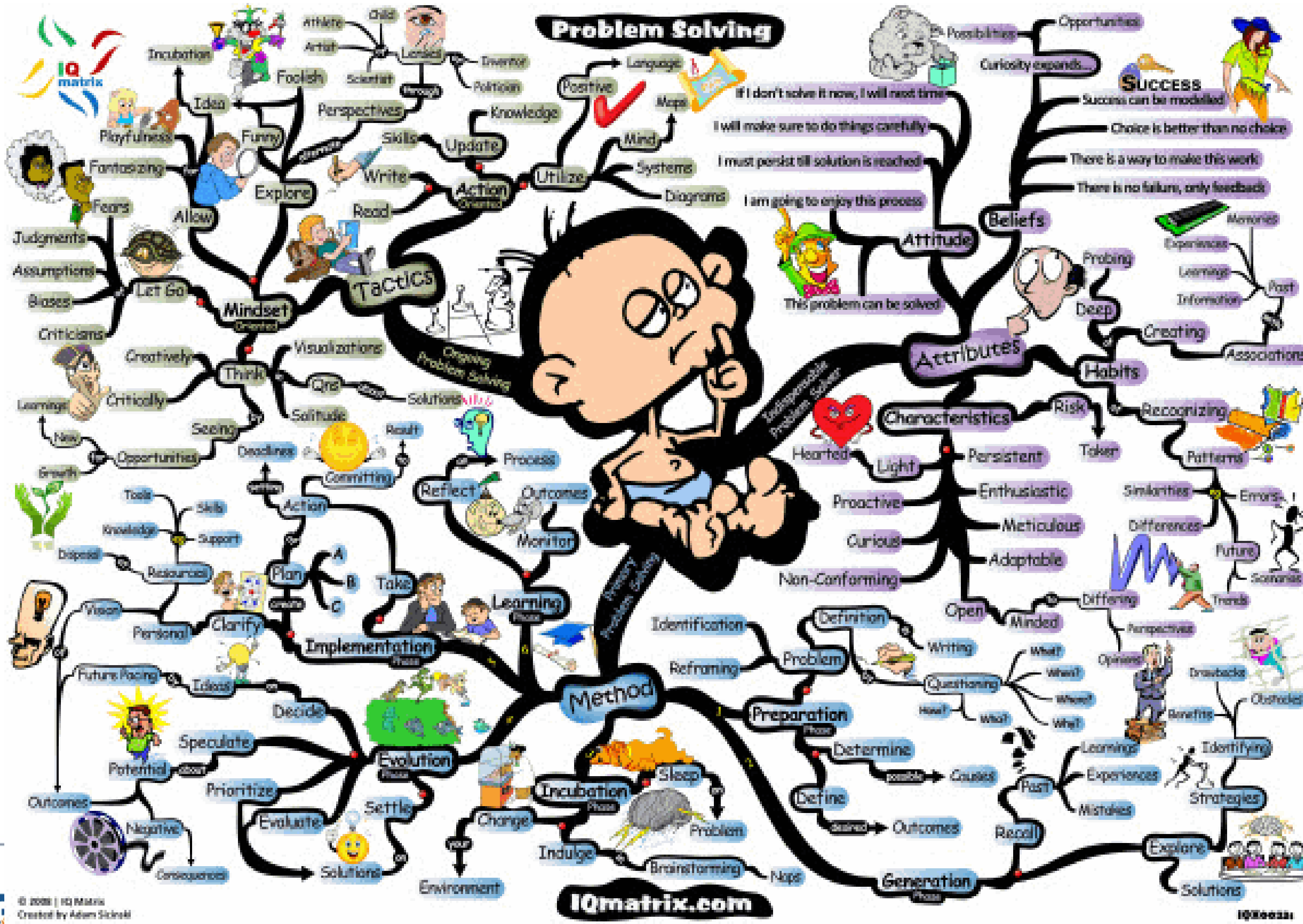
Evaluate



use-less objects all handmade
hammer
item # 1. useless hammer made to order. every one slightly different.
Our most-requested item. The Mgmt.
nice metal head
handle is handcrafted from 75-year-old red maple
"It doesn't work."
(says J.W. of Cincinnati)
rolling pin
item # 2. useless rolling pin made to order. every one slightly different.
75-year-old red maple
"My pastry looks awful."
(writes "Peeved" of Junction City, KS)

use-less objects all handmade
t-square
inconveniently set at 17.5°
"No good unless you need everything at a 17.5° angle."
(says M.B. of Pendleton, OR)
item # 3. useless t-square made to order. every one slightly different.
garden rake
"Hopeless."
(says Mary of Medford, NJ)
item # 4. useless rake made to order. every one slightly different.
hinge
hinge
hinge
hinge
hinge
hinge
nice metal "comb"
Our 2nd most-requested item. The Mgmt.
ruler
"It's terribly wrong."
(says Eric R. of Shreveport, LA)
not really straight
item # 5. useless ruler made to order. every one slightly different.

Self-Defined Problems



Design Science

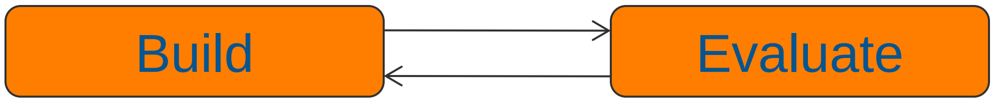
- Term originally introduced by (Fuller and McHale in 1963)

- Design Science in IT coined by March and Smith in (March and Smith: Design and natural science research on information technology, DSS, (15), 1995)
  - IT research studies **artificial** (human creation) phenomena
  - Artificial phenomena can be **created and studied**
  - IT research can contribute to **both activities**

- Seminal contribution of (Hevner et al.: Design Science in Information Systems Research, MISQ, 28(1), 2004)

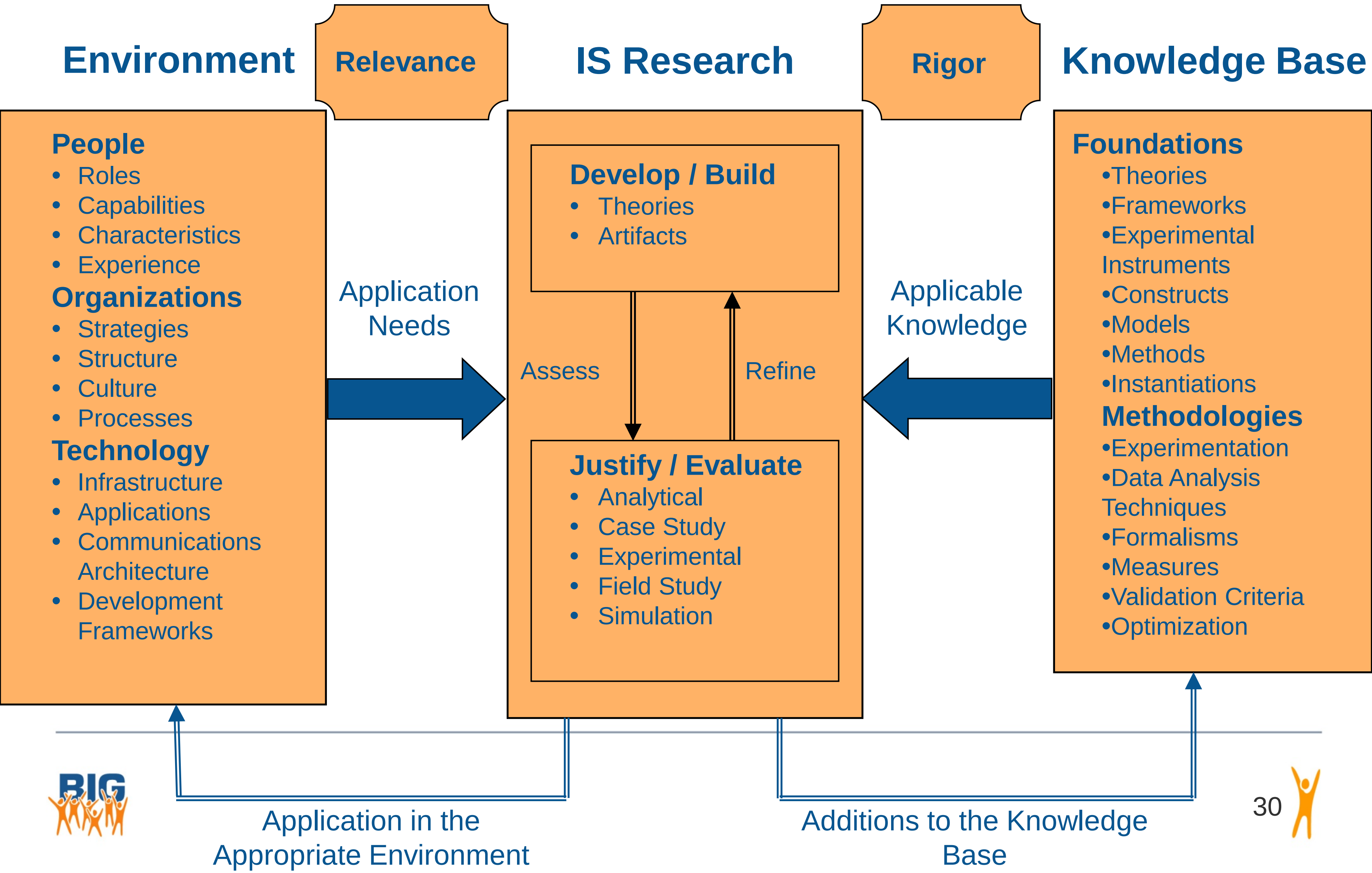
Design Science
Activities and Products

- Design science consists of two basic activities



- Performance of the built artifact is related to the environment
  - → Requires understanding of the environment
  - → Anticipating the potential side-effects of the artifact's use
  - → **Challenging to evaluate!**

- Design science products are of four types
  - Constructs
  - Models
  - Methods
  - Implementations


Environment
Relevance
IS Research
Rigor
Knowledge Base
People
• Roles
• Capabilities
• Characteristics
• Experience
Organizations
• Strategies
• Structure
• Culture
• Processes
Technology
• Infrastructure
• Applications
• Communications Architecture
• Development Frameworks
Application Needs
Develop / Build
• Theories
• Artifacts
Assess
Refine
Justify / Evaluate
• Analytical
• Case Study
• Experimental
• Field Study
• Simulation
Applicable Knowledge
Foundations
•Theories
•Frameworks
•Experimental Instruments
•Constructs
•Models
•Methods
•Instantiations
Methodologies
•Experimentation
•Data Analysis Techniques
•Formalisms
•Measures
•Validation Criteria
•Optimization
Application in the Appropriate Environment
Additions to the Knowledge Base

Research in Business Informatics
Attention: Here constructive approach

Analysis → Design → Evaluation

- Analysis
  - Relevance
  - Perception of characteristics of the investigated object
- Design
  - Result of the design
    - Models
    - Methodologies
    - Prototypes
    - Anyway: Abstraction of the “object” / real system
  - Principles of Design
    - Correctness
    - Relevance
    - Efficiency
    - Clarity, Simplicity
- Evaluation
  - Rigor demands for evaluation of the created artifacts
  - Using the goals stated at the beginning

Methods by phase

- Analysis phase
  - Surveys, case studies, expert interviews, …
- Design
  - Modeling, Prototypes, theory / method development, ..
- Evaluation
  - Laboratory experiments, field studies, simulation, …

Design Science Guidelines [Hevner]

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Finally: Knowledge Contribution Framework

Solution (Artifact) Maturity	High Application Domain (Problem) Maturity	Low Application Domain (Problem) Maturity
Low	**Inspiration**: Develop new solutions for known problems *Research Opportunity*	**Invention**: Invent new solutions for new problems *Research Opportunity*
High	**Routine Design**: Apply known solutions to known problems	**Exaptation**: Extend known solutions to new problems (e.g. Adopt solutions from other fields) *Research Opportunity*

High Low

Application Domain (Problem) Maturity

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Produce a viable artifact

- Artifact may be
  - Constructs
  - Models
  - Methods
  - Instantiations
- Artifacts are rarely full-grown IS
  - Commonly not used in practice

- Artifacts are "innovations" defining
  - Ideas
  - Practices
  - Technical capabilities
  - Products

… through which the analysis, design and implementation can be effectively accomplished.

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Solve Important and Relevant (Business) Problems

- Problem: difference between a goal state and the current state
- Problem solving: Searching for actions reducing this difference
- e.g., Business goal criteria
  - Increasing revenue
  - Decreasing costs
- Others ? (we are not only business driven?)

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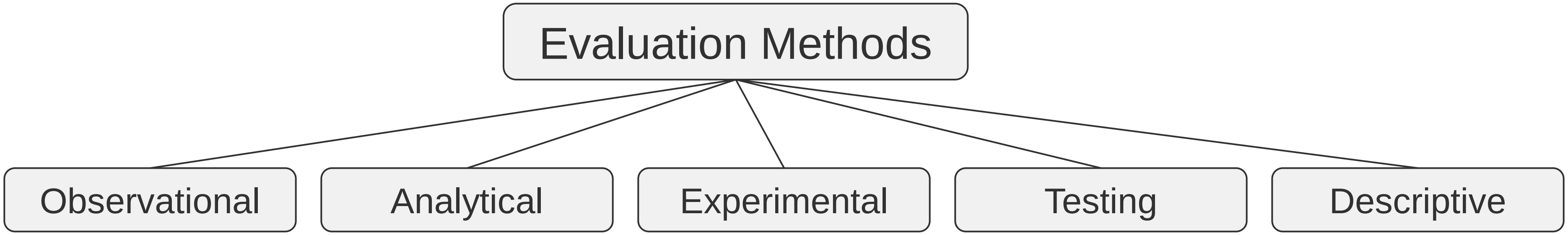
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact

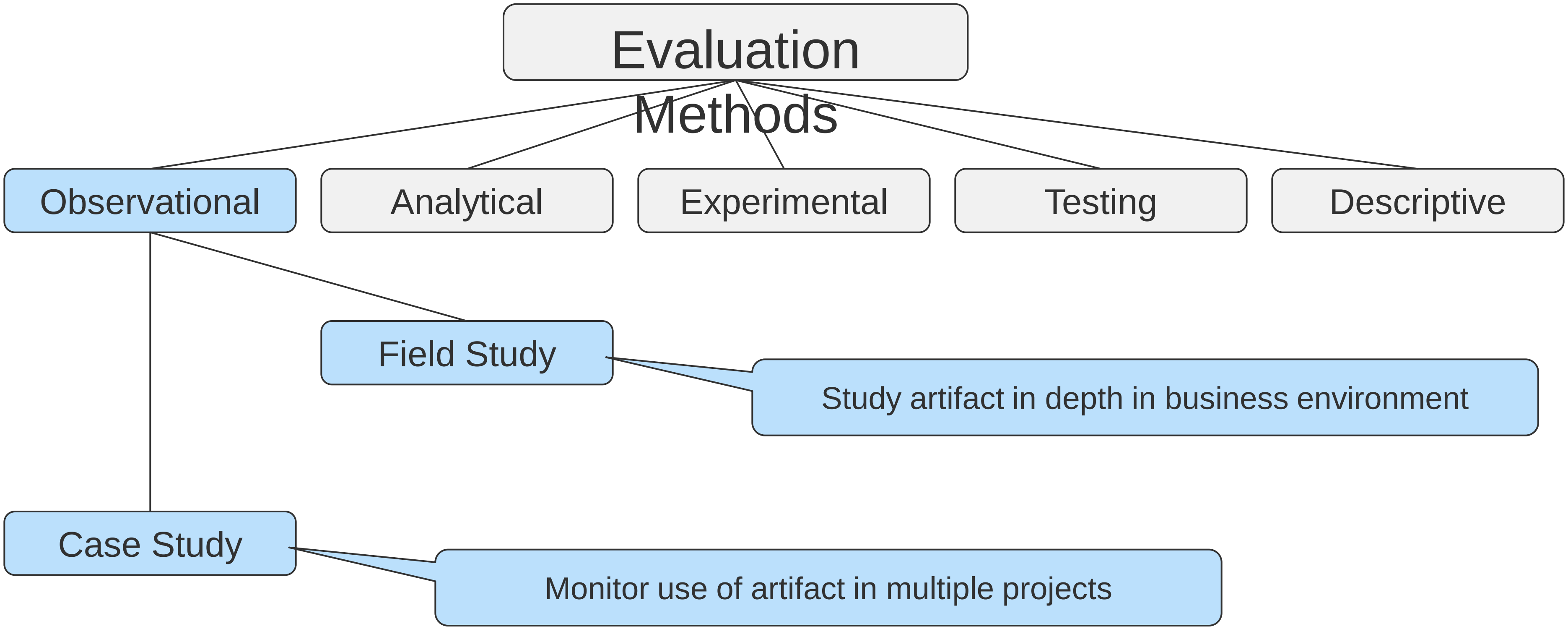
Design Evaluation

- IT artifacts are evaluated in terms of
  - Functionality, Completeness,
  - Consistency, Accuracy,
  - Performance, Reliability, Usability
- Design is inherently an iterative and incremental process
  - Evaluation phase provides feedback to the construction phase

Design Evaluation Methods



Design Evaluation Methods



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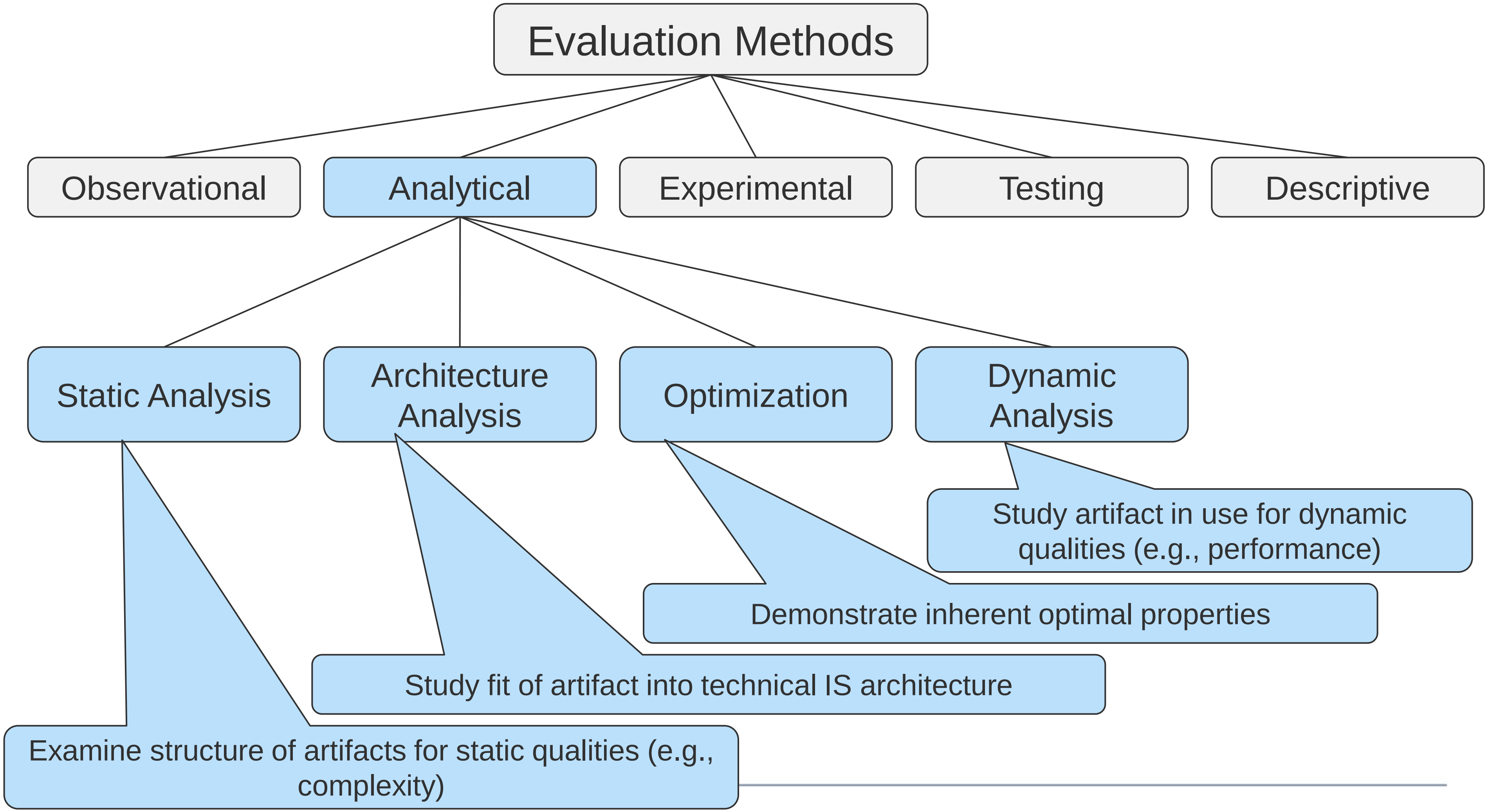

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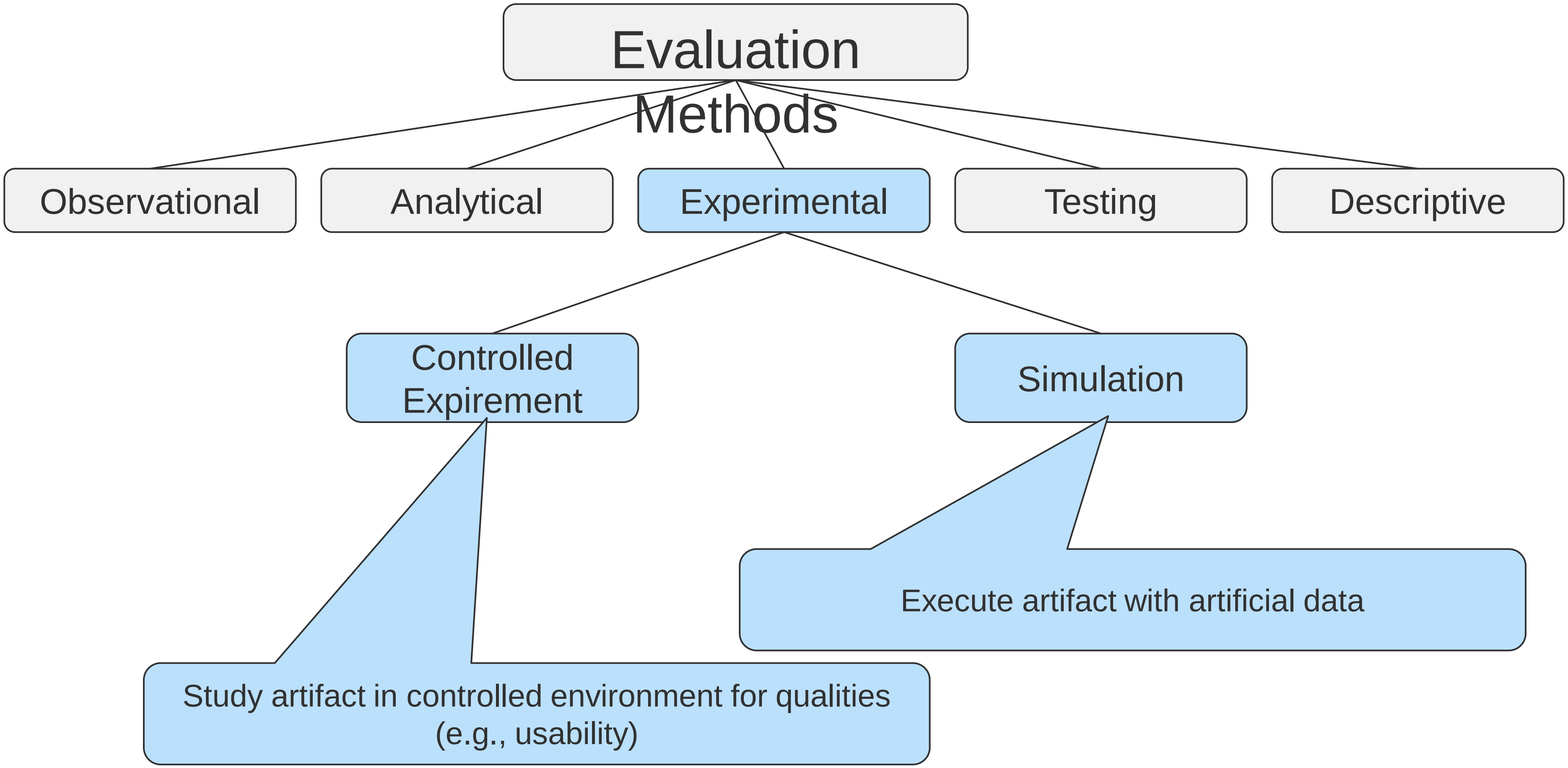
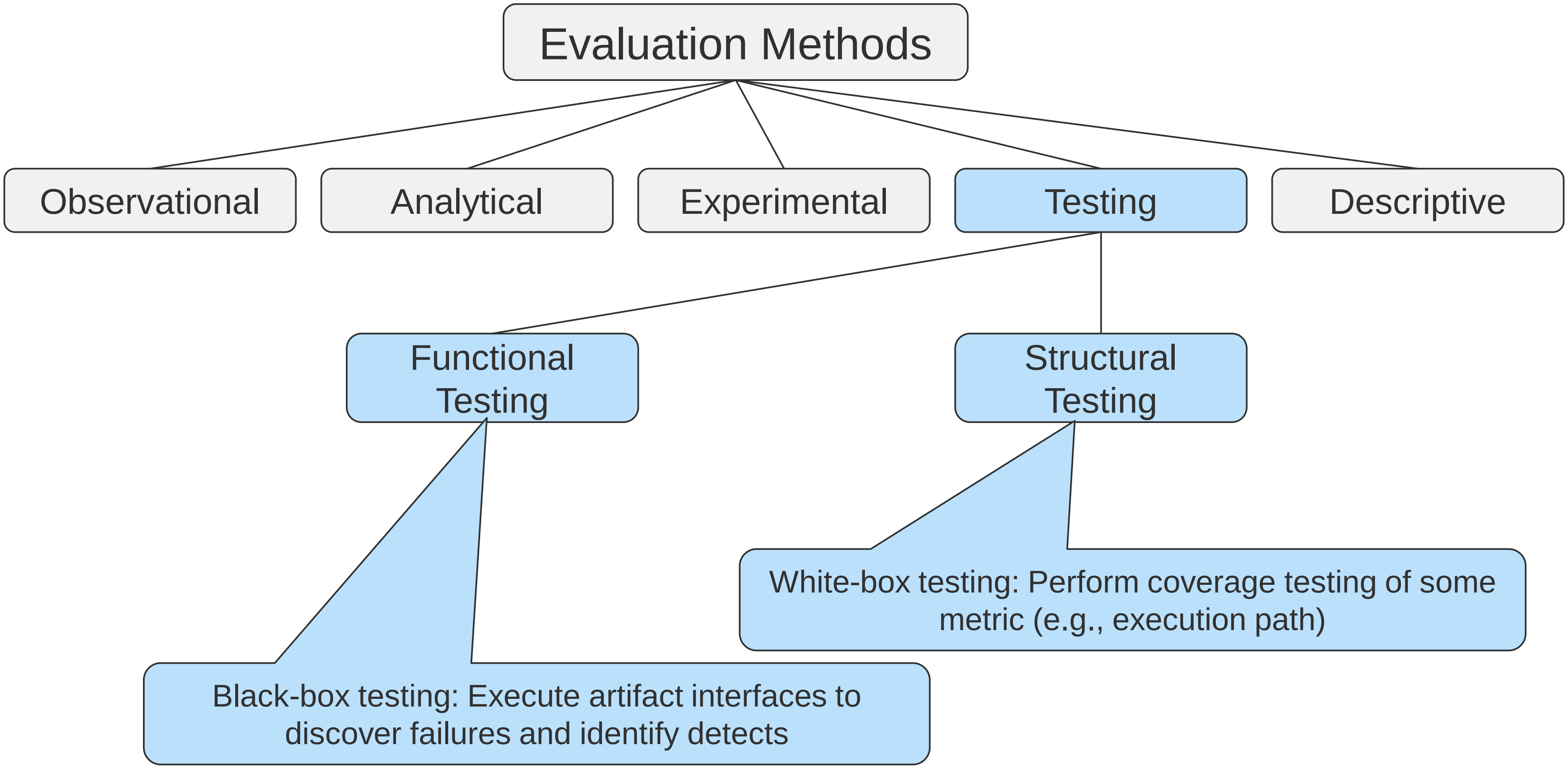
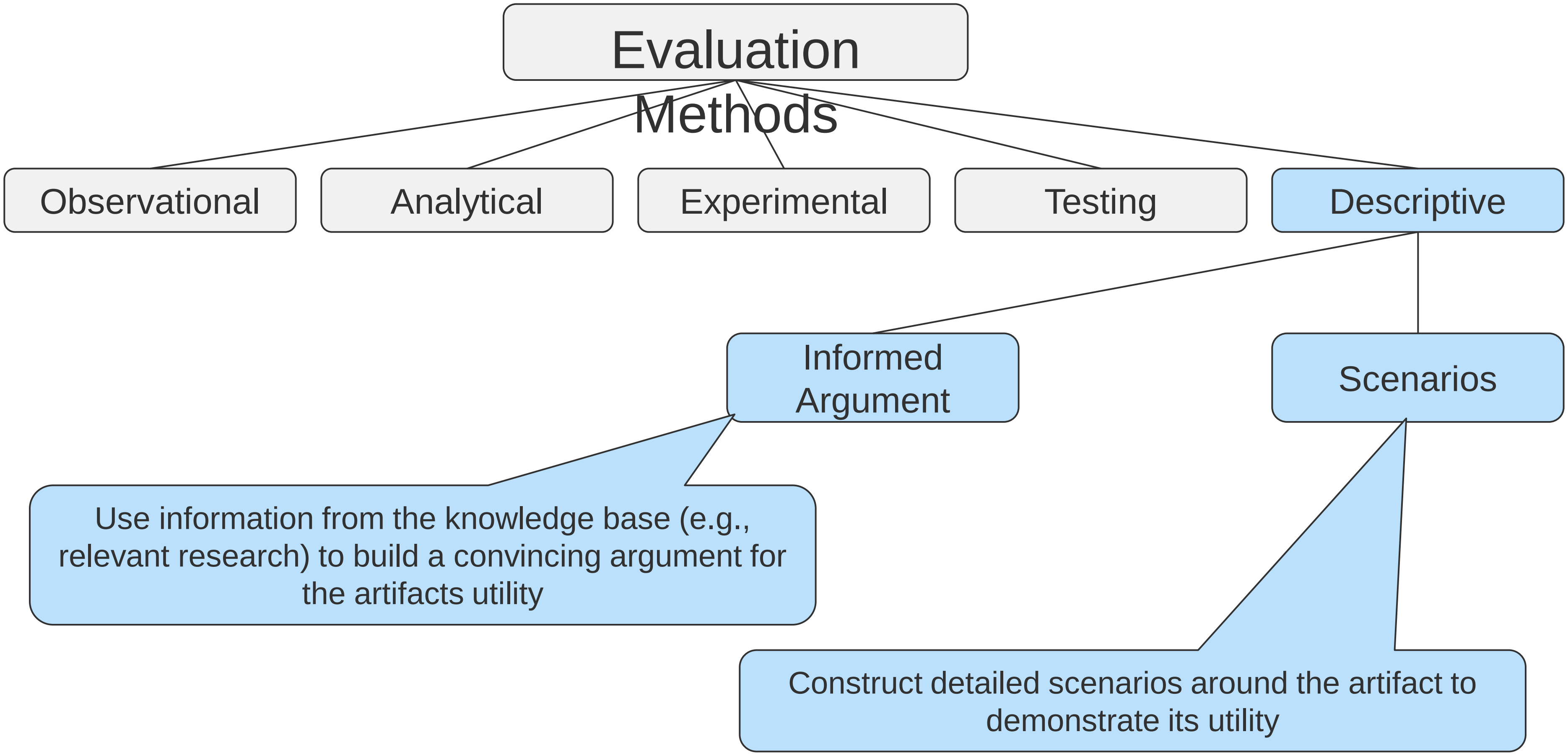


Design Evaluation Methods



Design Evaluation Methods



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Guideline 5: Research Rigor	Design-science research relies upon the application of

Three types of contributions

- Design artifact itself
  - Solution of heretofore unsolved problems
  - Apply existing knowledge in new and innovative ways
- Foundations
  - Novel constructs (models, methods, or instantiations)
  - Extending the existing knowledge base
- Methods

Design Science Guidelines

Rigor

- Rigorous research techniques in all phases
- Rigor is derived from effective use of the knowledge base
  - Theoretical foundations
  - Research methodologies
- The challenge is to find
  - Appropriate techniques to develop a theory
  - Appropriate means to justify the theory
- Components of human-machine problem-solving systems require
  - Behavioral theories and empirical work
- And building an artifact relies on mathematical / logical foundations to describe the specified and constructed artifact
  - E.g., principles of Abstraction and Hierarchical Decomposition to deal with complexity
- Attention: again both sides (analytical and constructive)

Design Science Guidelines

Design as a Search Process

- Wicked nature of many IS design problems
  - → Huge size and complexity of solution space
  - → Rendering a problem might be computationally infeasible
- Picking a potential solution out of the solution space requires
  - Creativity
  - Innovation
  - Heuristics
- Good design is based on iterative, heuristic search strategies
  - Simon's Generate/Test Cycle
  - Problem Simplification and Decomposition
- The Search for Optimal Solutions may not be feasible or tractable

Guideline	Description
Process	means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

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Communication of results
Heterogeneity of audience

- Application / Management-oriented audience
  - Need to decide if organizational resources should be committed to constructing and using “your” artifact

  → No pure emphasis on the artifact itself

  → Emphasis on the knowledge required to effectively apply “your” artifact
- Science-oriented audience
  - Needs sufficient detail to understand and construct “your” artifact
  - And detail on your design rationale (why you did what you did)

Research Principles (Österle et al.)

- **Abstraction**:
  Each artifact must be applicable to a class of problems.
- **Originality**:
  Each artifact must substantially contribute to the advancement of the body of knowledge.
- **Justification**:
  Each artifact must be justified in a comprehensible manner and must allow for its validation.
- **Benefit**:
  Each artifact must yield benefit – either immediately or in the future – for the respective stakeholder groups.

YOUR THESIS

Identify/ Formulate Research Question

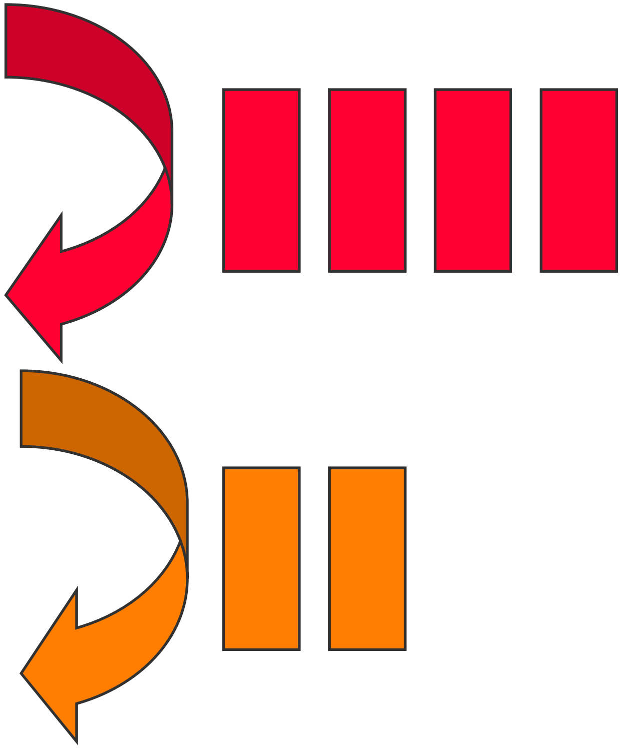
Three Levels:

1. There is the problem and you don't see it

2. There is the problem, you see it but you don't know how to solve it

3. There is the problem, you see it and you know how to solve it

Difficulty:

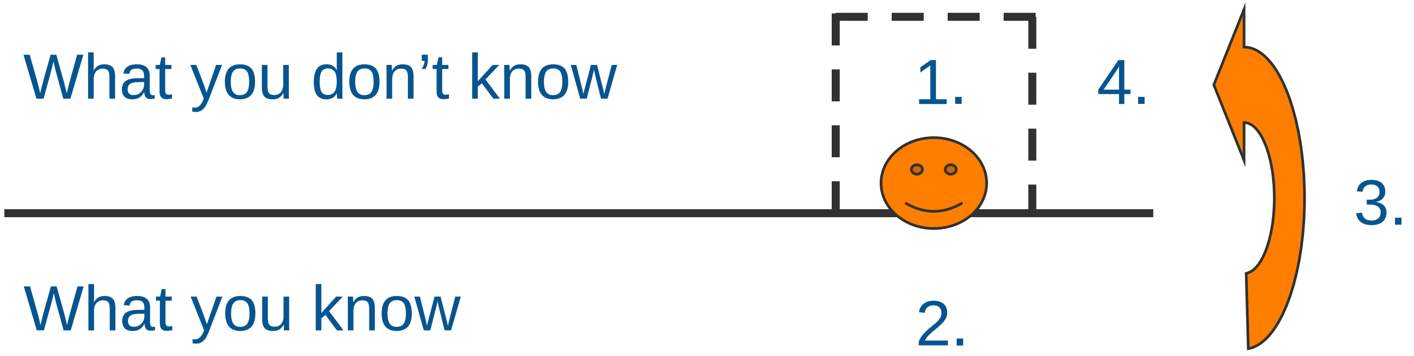


Define the contribution

- What is your contribution?
- (a new technique, a new experimentation)
- What do you try to do?
- How will you do this?
- What is the core idea?

- Do you like it (you have to “live” with it) ?
- Organize / structure by goals
- Develop a time-plan

Setting Goals



Iterations

1. Objectives
2. Your knowledge (or better: state of the art)
3. You can do it (next step) – apply methods
4. Solve

Proposal

Don’t forget: Important Step

You know your topic and your advisor
(Attention: choice of advisor [senior vs. time])

Proposal

- Problem / Research Question
- Expected Result
- Approach
- State of the art

Make a “To-Do” list

Set a priority for goals, e.g.,

- Priority A
  - Critical, but may be unpleasant to do
  - Goal related
  - Must be done today
- Priority B
  - Important
  - Goal Related
  - Must be done soon, but not today
- Priority C
  - Can wait
  - May or may not be goal related
  - Usually easy, quick and pleasant

Important

Importance of **FOCUS** & **FOCUS**

Decide what is your main focus / story / contribution

- ‘Der rote Faden’ – central theme
- Go for SIMPLE, ideally SINGLE, clearly linked to research question

Write it down, maybe use bullet points to structure

- Can still evolve or change as you work with your material
  - But at least you always know where you are…

Flexibility and Openness

Flexibility:

maintain context, be ready to change context

Openness:

new ideas may come from boundary between areas

But:

Know what you don’t know / where is the boundary

Know what, when, where and whom to ask

Basic elements – Structure of work

1. Introduction
   - Context setting & Motivation (Why should we care?)
   - Problem statement and aim
   - Describe roughly how you will do it (meth. approach)
   - Structure of your work
2. State-of-the art
   - Also: What’s the gap you are trying to address?
3. Methods/procedure/approach
   - How did you approach it? What did you do?
4. Results/findings/product
   - What’s the answer? What did you learn/invent/create?
   - How did you evaluate?
5. Conclusions/implications
   - What have you done
   - What are the larger implications?
   - What is missing
6. Bibliography (and appendix)

Writing

….. is story telling

Guide the reader from sentence to sentence, paragraph to paragraph, section to section [Flow]

Guide the reader along each step of the story [Content]

Don’t assume anything … be explicit, make thinking clear

No surprises

No ambiguity or second guessing

Writing ….

Every section tells one sub-story – linear flow

Importance of orientation at key transitions – usually at beginning or end of sections

- ‘So far we have … next we will …’

Every paragraph contributes one point to the story

Top-down style

- First sentence points to what the paragraph is about
- Tipp: can also read first sentences of each paragraph and see if you get the story

Language

Short simple sentences, simple words, no redundancy

‘in respect of’ -> ‘about’

‘in the event of’ -> ‘if’

‘absolutely critical’ -> ‘critical’

‘Taking into consideration such factors as …’ -> ‘Considering …’

Active rather than passive voice

‘Measurement of static software properties was performed by the tool’ ->
‘The tool measured static software properties’

Personal vs impersonal style

‘The authors’ results have shown’ <-> ‘our results show’

Example ‘Flag’ words, phrases

Help to mark the flow of the work, and may sign significant points / moves in structure etc

Similarly, in addition to…

But…

However, on the other hand…

So in this section… In the next section

The main contribution of this paper is … This is important …

The focus of this paper is …

… within scope … out of scope …

First, … Second, … Third, … Finally, …

Language (cont)

Define abbreviations, concepts, terms etc early (and provide an appendix for it)

Being aware of German/language influences

- Sentence structure, word order
- Complexity of expression
- Others?

Ideally, have the work proof read by a native speaker

- Poor writing may still subconsciously influence a reader’s judgment on the quality of the work

Other Tipps

Find people to read and critique your drafts

- Fresh eyes can make all the difference
- Catch the things you know but you have left unstated or fuzzy

Volunteer to be a reviewer yourself!

Finally

Watch web site of Deanery for forms, templates, dates, …

http://www.informatik.tuwien.ac.at/dekanat