5-1 Design Science Research

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Design Science Research

Guideline 1

- Design research involves the design of an ***artefact*** with the aim of better understanding or improving a theory

"Knowledge through making"

- Artefacts can be
  - ***constructs*** (e.g. formal languages, mathematical constructs like Petri nets)
  - ***models*** (representations of existing or possible real-world systems)
  - ***methods*** (processes, procedures, algorithms)
  - ***instantiations*** (implementation examples of constructs, models, or methods, e.g. in computer programs)

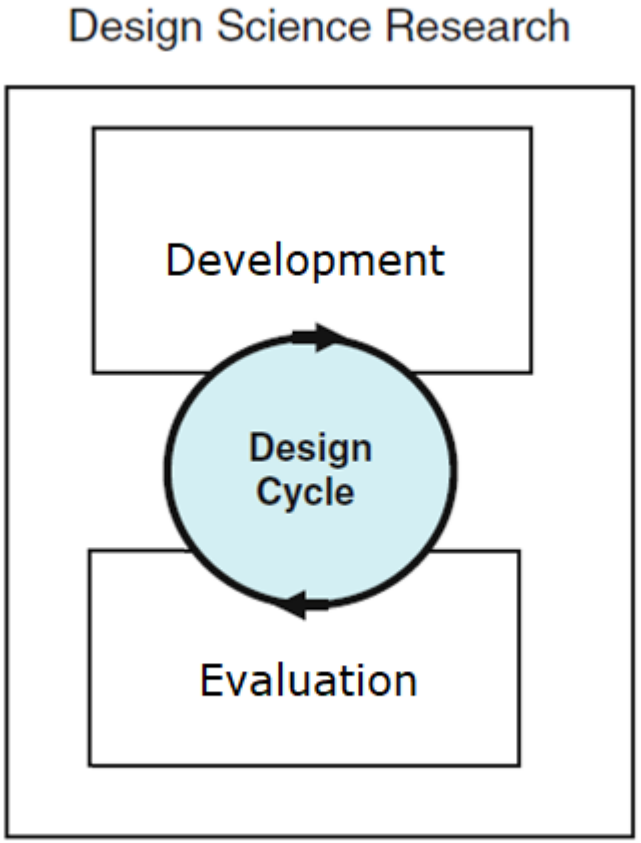
Design Science Research Guidelines

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
2	Problem relevance	The objective of design science research is to develop technology-based solutions to important and relevant business problems
3	Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods
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
5	Research rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact
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
7	Communication of research	Design science research must be presented effectively to both technology-oriented and management-oriented audiences

(Hevner & Chatterjee 2010)

Design Science Research Cycle

Guideline 1,6

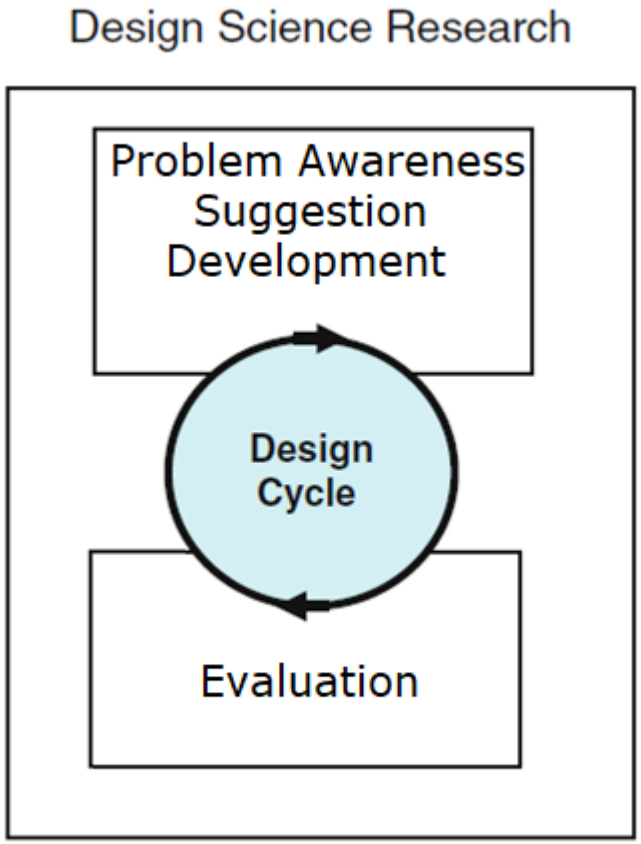


- The design science research combines
  - Development of an artefact
  - Evaluation of the artefact
- There can be several iterations of Development and Evaluation
- This is what is called the Design Cycle

Guideline 1,6

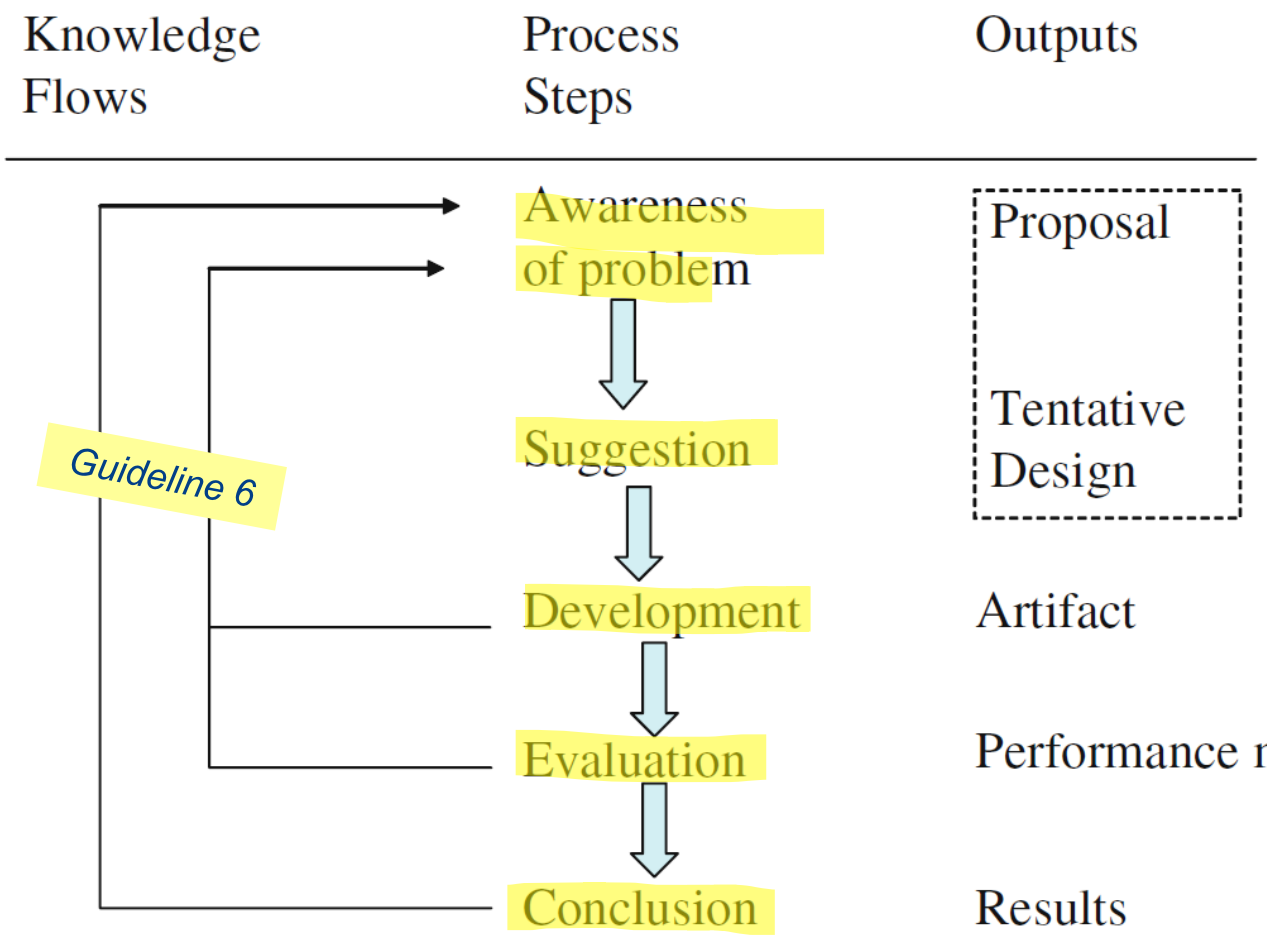
Process Steps in Design Research (1)

The Development Phase can be split in several steps



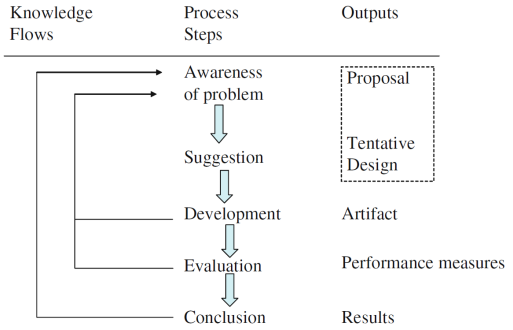
Process Steps in Design Research (1)

Guideline 1



(Hevner & Chatterjee 2010) adopted from (Vaishnavi & Kuechler 2004)

Process Steps in Design Research (2)



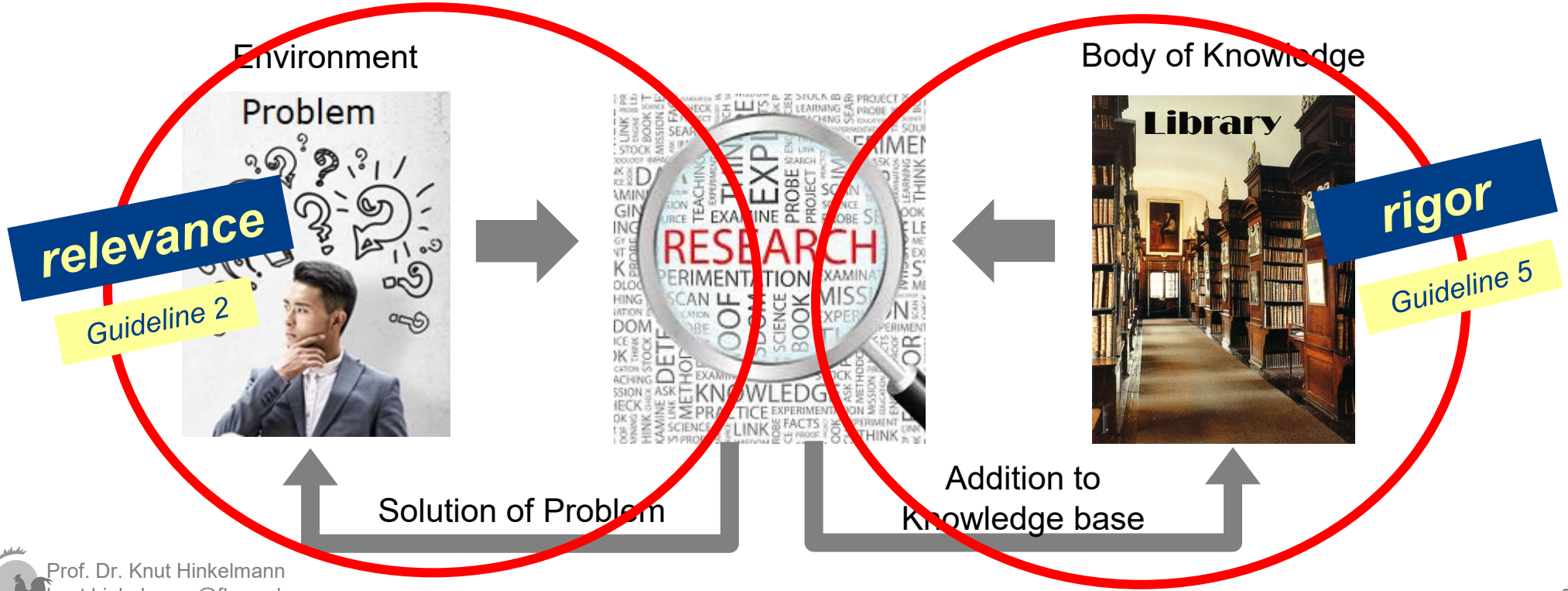
Phases of Design Science Research:

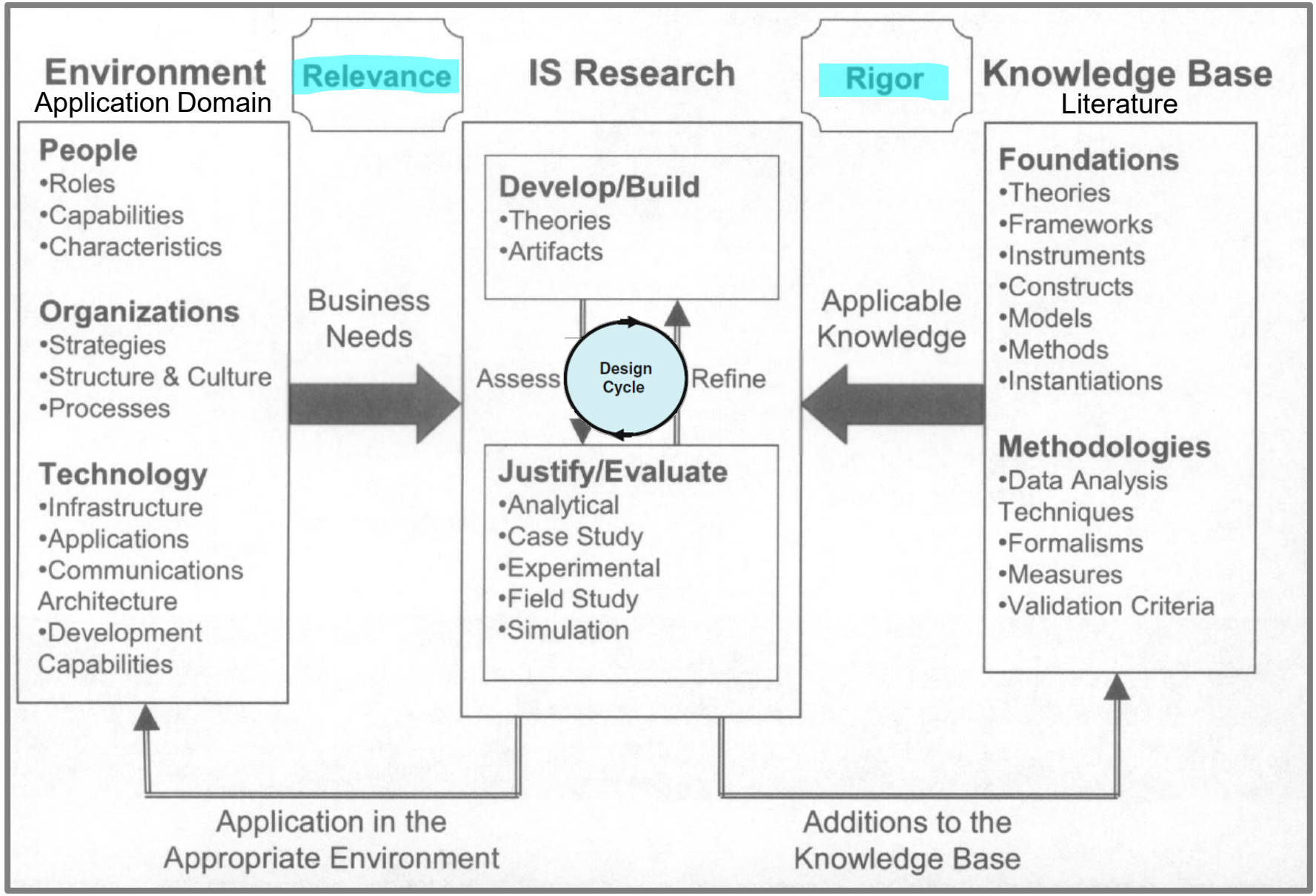
- Awareness of problem
  - recognition of a problem which can be solved by or using new artifacts
- Suggestion
  - discussing what kind of artifact might solve the problem
- Development
  - designing and creating the artifact
- Evaluation
  - checking whether the artifact solves the problem, analyzing its strengths and weaknesses
- Conclusion
  - compilation of results and future aspects such as open questions or plans for further development

(Hevner & Chatterjee 2010, p. 27), (Oates 2006, p. 111f)

Rigor and Relevance

- The intent of DSR is to create an artefact through a balanced process that combines
  - the highest standards of ***rigor***
  - with a high level of ***relevance***

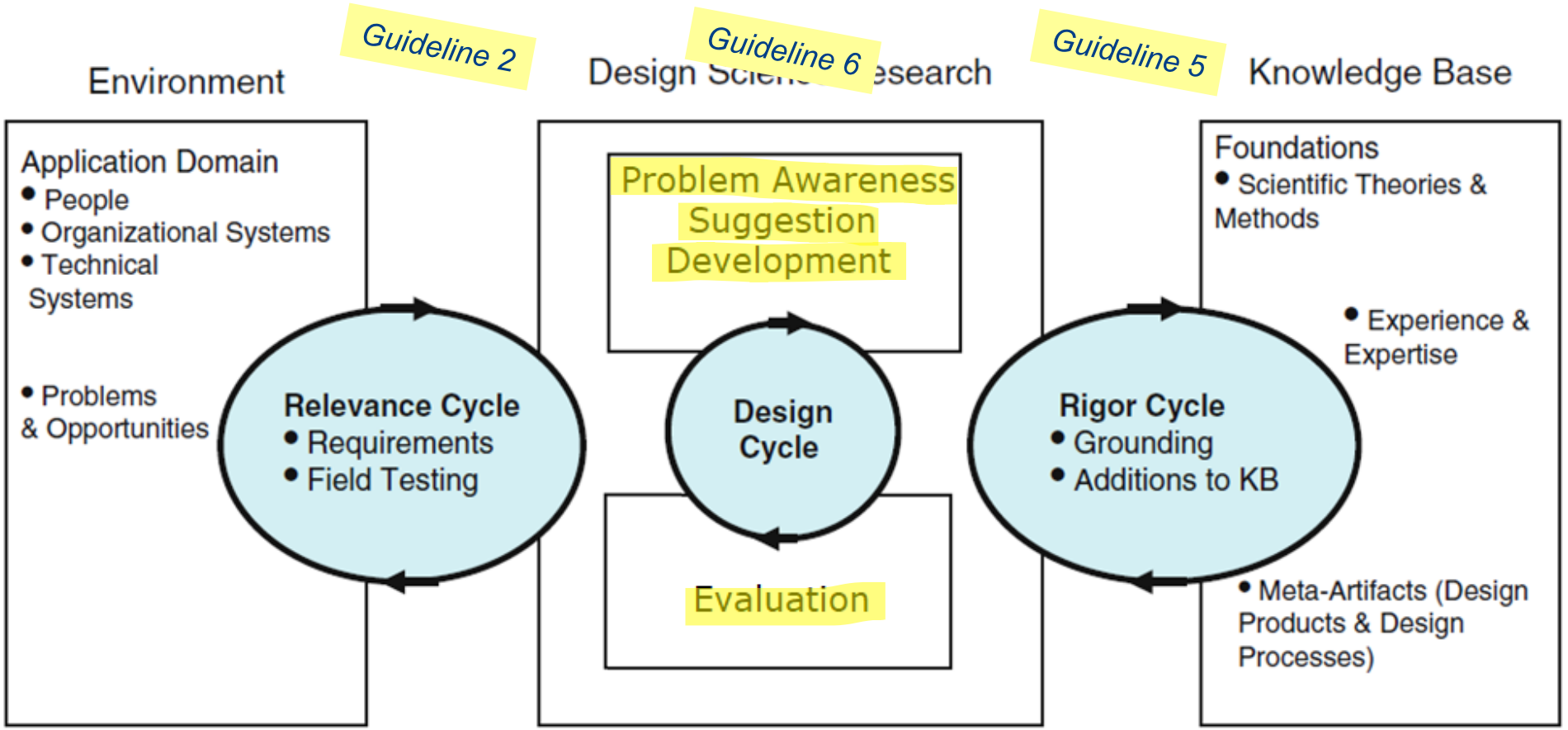




(Hevner et al 2004)

Rigor and Relevance in Design Research

Guideline 1



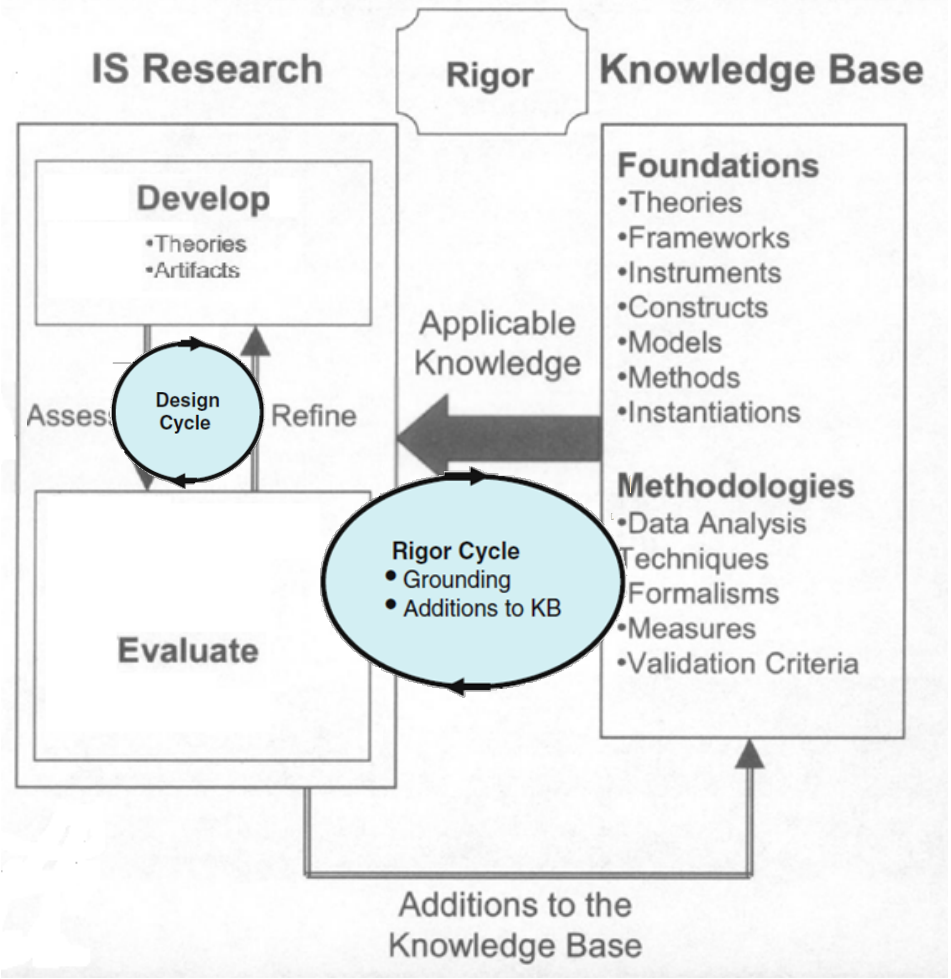
Relevance and Rigor Cycle refer to usefulness and novelty

Based on (Vaishnavi & Kuechler 2004) and (Hevner & Chatterjee 2010, p. 16)

Rigor Cycle: Strict Application of Scientific Method

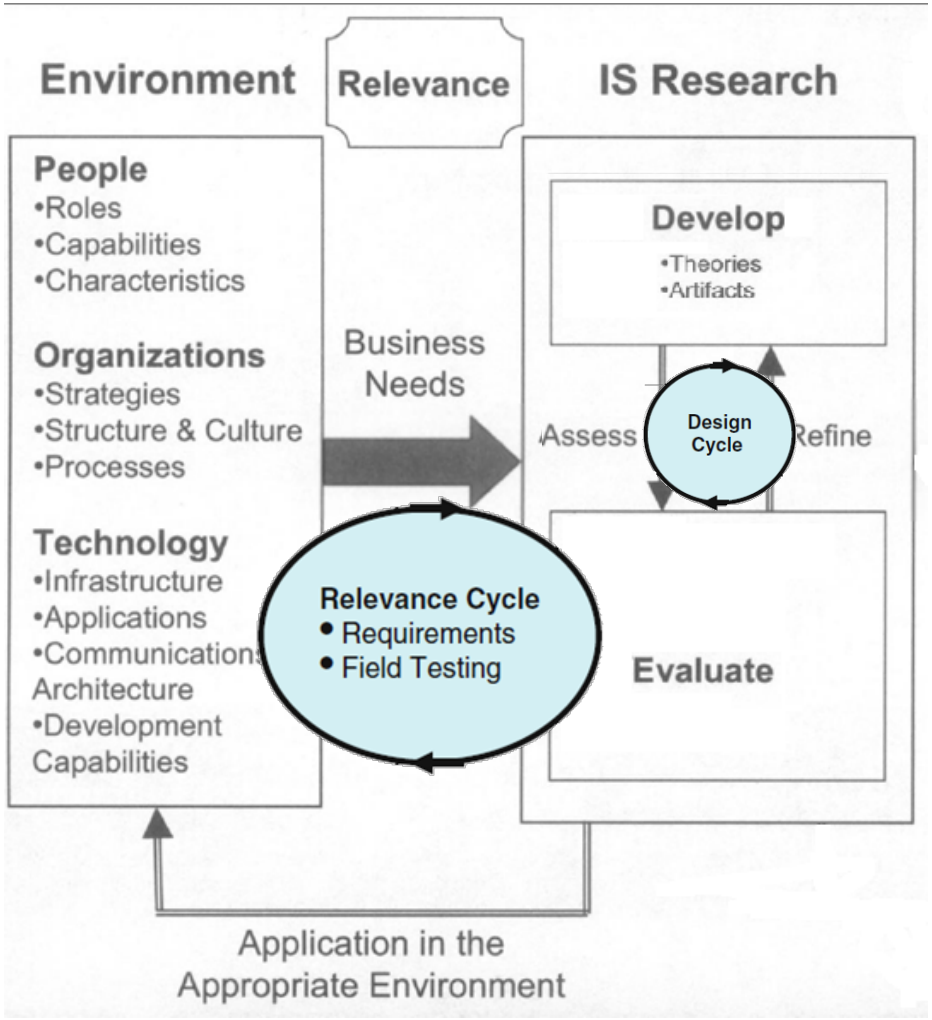
Guideline 5

- **Scientific rigor** as 'the strict application of the **scientific** method to ensure robust and unbiased design, methodology, analysis, interpretation and reporting of results.
- Rigor Cycle in Design Science Research
  - ♦ Using knowledge about
    - Foundations
    - Methodologies
  - ♦ Additions to the Knowledge Base



Relevance: Practice-Oriented Research

Guideline 2



- Relevance Cycle
  - Collect and analyse data from reality (requirements)
  - Artefact is applicable in practice

Guideline 2,5

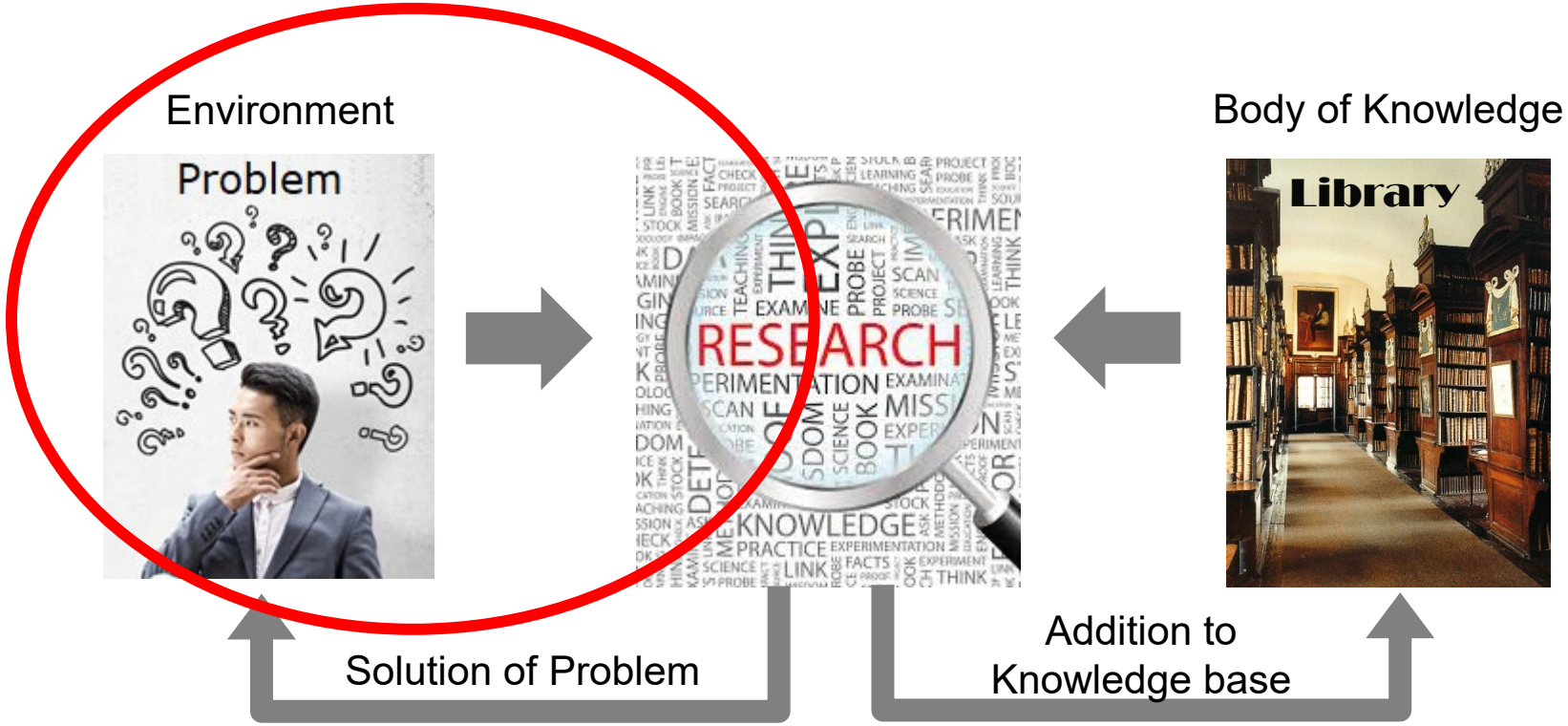
Rigor and Relevance in the Awareness Phase

- Awareness phase tries to get a deep understanding of the problem, **using analytical methods / techniques**
  - Roughly corresponds to requirements analysis in software engineering

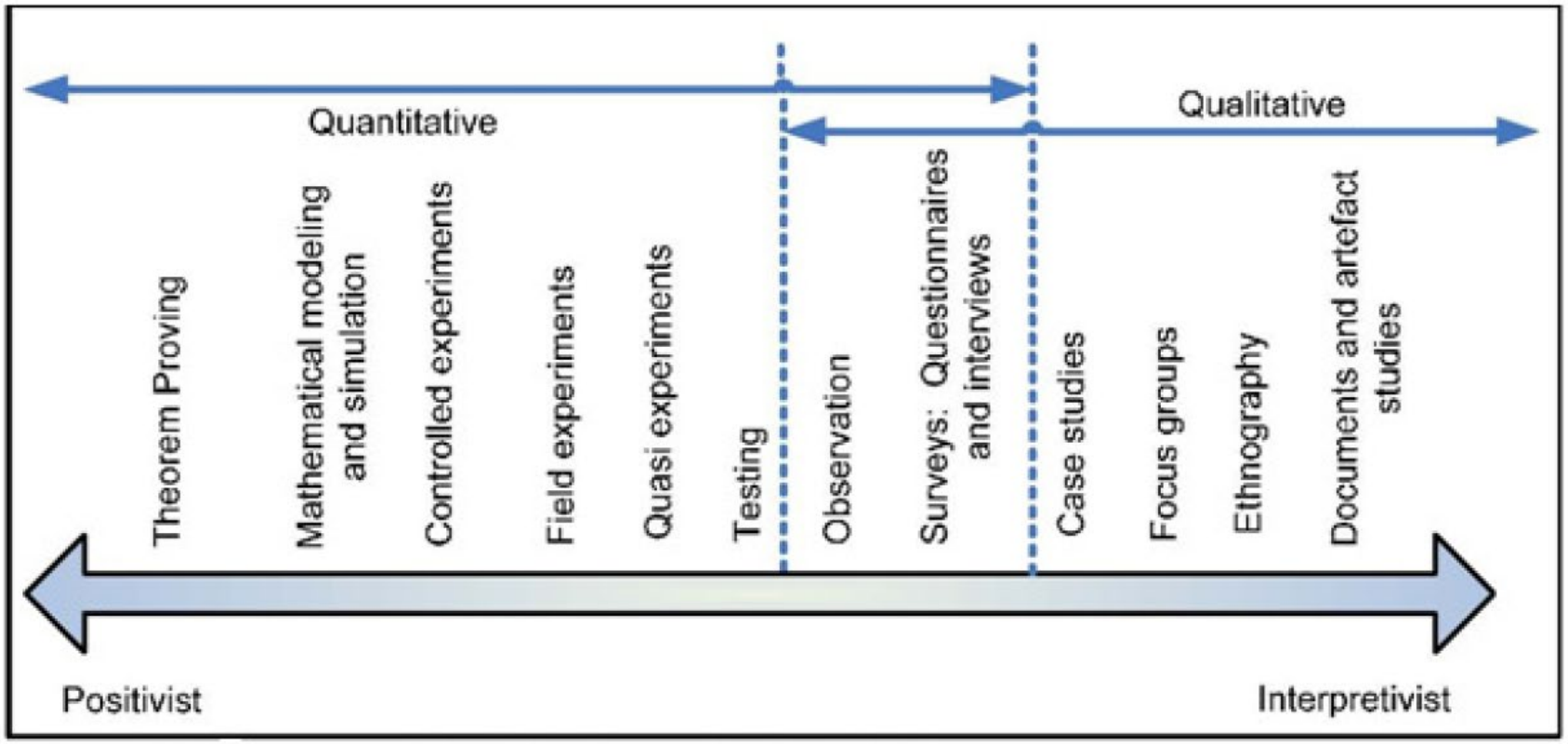
- Possible activities in the awareness phase
  - Literature research (state of the art) — ***rigor***
  - Studying existing practice using appropriate collection and analysis of primary data — ***relevance***
  - Studying experience reports and discussions (e.g. blogs) — ***relevance***
  - Studying secondary data (e.g. studies, statistics) — ***relevance***

Data support Relevance

- With data you analyse your environment (application domain)



Methods for Data Collection and Analysis



(De Villiers 2005)

Rigor and Relevance in the Suggestion Phase

Guideline 2,5

- Suggestion phase explores possible solutions for the problem
  - Roughly corresponds to conceptual design in software engineering

- Possible activities in the suggestion phase
  - Literature research for solution alternatives
  - Feedback from practice (e.g. interviews, focus groups, workshops)
  - Studying experience reports

rigor

relevance

Novelty and usefulness of an artifact

When does an artifact constitute research?

- it must be sufficiently new - with respect to knowledge base
  - thus, it must sufficiently differ from existing artifacts
  - this can be proven by a careful literature review

rigor

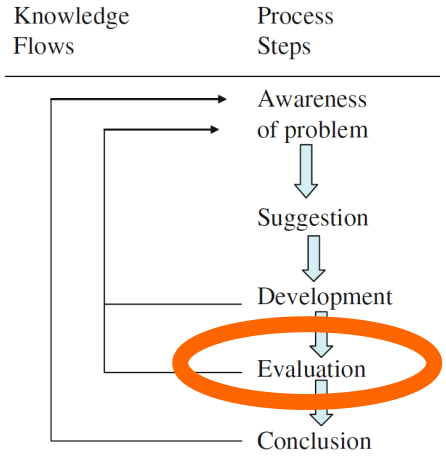
- it must be sufficiently useful – with respect to environment
  - artifact is something fundamentally new
    - e.g. a new computer language, a new modeling concept, a new method
  - applied in a new domain (replication)
    - e.g. an information system used in a new field
  - adapted for a a new domain (modification, extension)
    - e.g. a learning theory is demonstrated, analyzed, or supported by an e-learning package

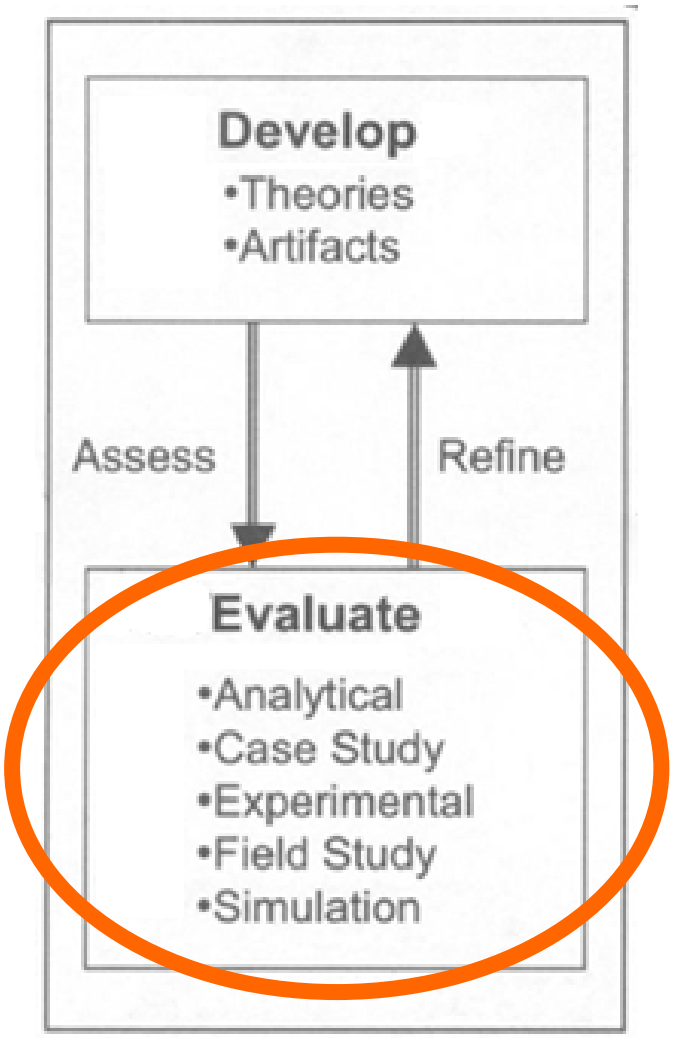
relevance

adapted from Thomas Hanne

Evaluation in Design Science Research

Guideline 3





- Examine whether the artifact meets the requirements.
- Evidence-based evaluation: evaluate the artifact within the application environment.

relevance

- Critical assessment of the artefact: identify possible weaknesses

Guideline 3

What and how to evaluate in Design Research

- Depending on the artifact, there are different aspects that can be evaluated, for example
  - performance (of a technical system)
  - organizational impact
- There are different evaluation methods, e.g.

What to evaluate	Evaluation Methods
Performance	analytical modeling, simulation, experiment, measurement, testing
Organisation impact	case study, quantitative surveys, qualitative interviews, focus groups, questionnaires, observation

Evaluation Methods (1)

Guideline 3

- *Measurements / Observational Case Studies*
  - Study the designed artifact in depth in a real environment.
  - Observe the use of the artifact to gain understanding of its value and utility.
  - Measurement is typically used for Performance Evaluation
  - *Metrics* are criteria for variables to evaluate the performance, e.g.
    - efficiency (time required, use of resources, scalability)
    - effectiveness (accuracy, quality of results)

Problems with Measurements

Guideline 3

- Putting system into practice is not possible
  - Changing processes or organisation structure required
  - Technical integration of a system is additional effort
- Not enough time to make the measurements
  - Observing effect of an artefact might require weeks or months
- Artefact is not executable (framework, concept)
- Data not available
  - To analyse effect of an artefact it often has to be compared to previous situation for which historic data is missing
- Did we take into account the appropriate data?
- Did the artefact really cause the effect that were measured?

Evaluation Methods (2)

Guideline 3

Alternative evaluations, if you cannot measure the artefact in a real environment:

- *Descriptive* evaluation
  - Informed argument uses information from knowledge base to build a convincing argument for artifact's utility.
- *Scenarios construction*
  - construct detailed scenarios around artifact to demonstrate its utility.
- *Experimental* methods
  - controlled experiments in which you study the artifact in controlled environment for qualities (e.g., usability).
  - *simulation* models: execute the artifact with artificial data and observe dynamic performance behavior and scalability.
- *Analytical* techniques
  - examine the structure of the artifact for static qualities (e.g., complexity, architecture) or behaviours

Critical Evaluation

Guideline 3

- The evaluation should be critical in order to provide evidence
- Even if not applicable in a real scenario, you have to allow and stimulate a critical assessment of your artefact
  - Construction a scenario in which the systems is used and assessed
  - Make a workshop in which the artefact is evaluated be several people (maybe covering different perspective), e.g. focus group
- Be careful with interviews:
  - Often too shallow – interviewee must be very familiar with the artefact
  - Critical setting: Determine weaknesses, not ask for confirmation

Problems of Design Orientation

- Success criterion: relevant, useful results
- Validation often by
  - implementation in practice
  - economic payoff
- Consequence:
  - Many publications of results are without rigouros, scientific evidence
    → no research

Goal: Simultanuous achievement of
- Design orientation
- Scientific rigor

based on (Österle et al. 2010)

Structure Design Science Research with Research Questions

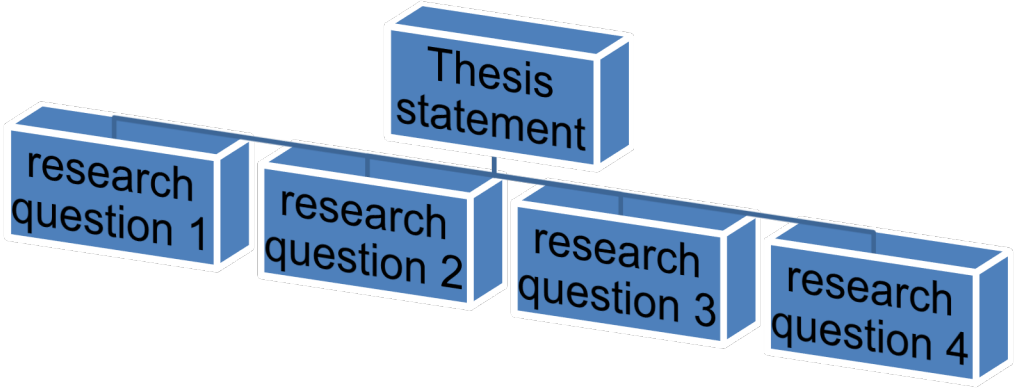
Thesis Statements in Design Research

- Thesis statements in design research are often referring to an **artefact** and the **benefit / business value** of the artefact
  - ♦ Evaluation should validate this claimed benefit
- Eample

  "It is possible to develop a system based on Natural Language Processing that recognizes if students copied from each other when writing their assignments."

Breakdown of the Thesis Statement into Research Questions

- The thesis statement specifies your contribution to the research problem
- Research questions break down your thesis statement into manageable tasks
- Each research question corresponds to a step in your research



Typical Breakdown of a Thesis Statement into (Sub-)Research Questions in Design Research

- Rule of thumb: Have a research question for each phase
- Example
  - Thesis statement: *"It is possible to develop a system based on Natural Language Processing that recognizes if students copied from each other when writing their assignments."*

Phase	Objective	Research question (generic)	Research question (example)
Awareness of problem	Understanding the problem	How is it done today? What problems are people facing?	How do lecturers recognize copying today? What are examples? What do students do to hide that they copied?
Suggestion	Explore characteristics and alternatives of an artefact	Which methods can be used? What are features of an artefact?	How can similiarities of texts be recognized? Which NLP tools can be used?
Development	Create an artefact	How can the artefact be realized?	How can the tools be integrated?