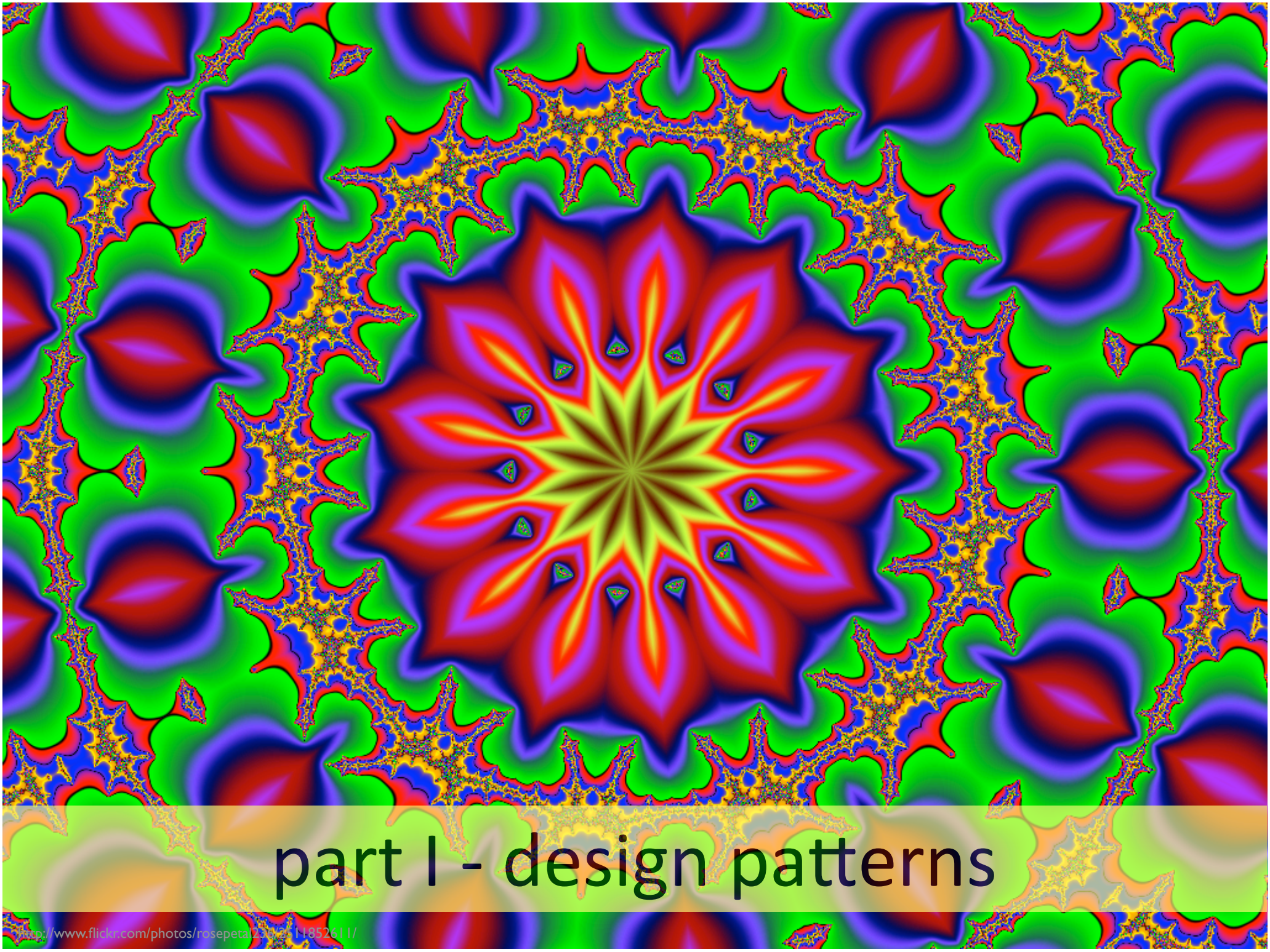
design science
research in IS

prepared by yves pigneur
DRIS April 2012

4

1. framework & publication
2. theory & anatomy
3. methodology & action design
4. **patterns & evaluation**
5. design rationale (C-K)



part I - design patterns

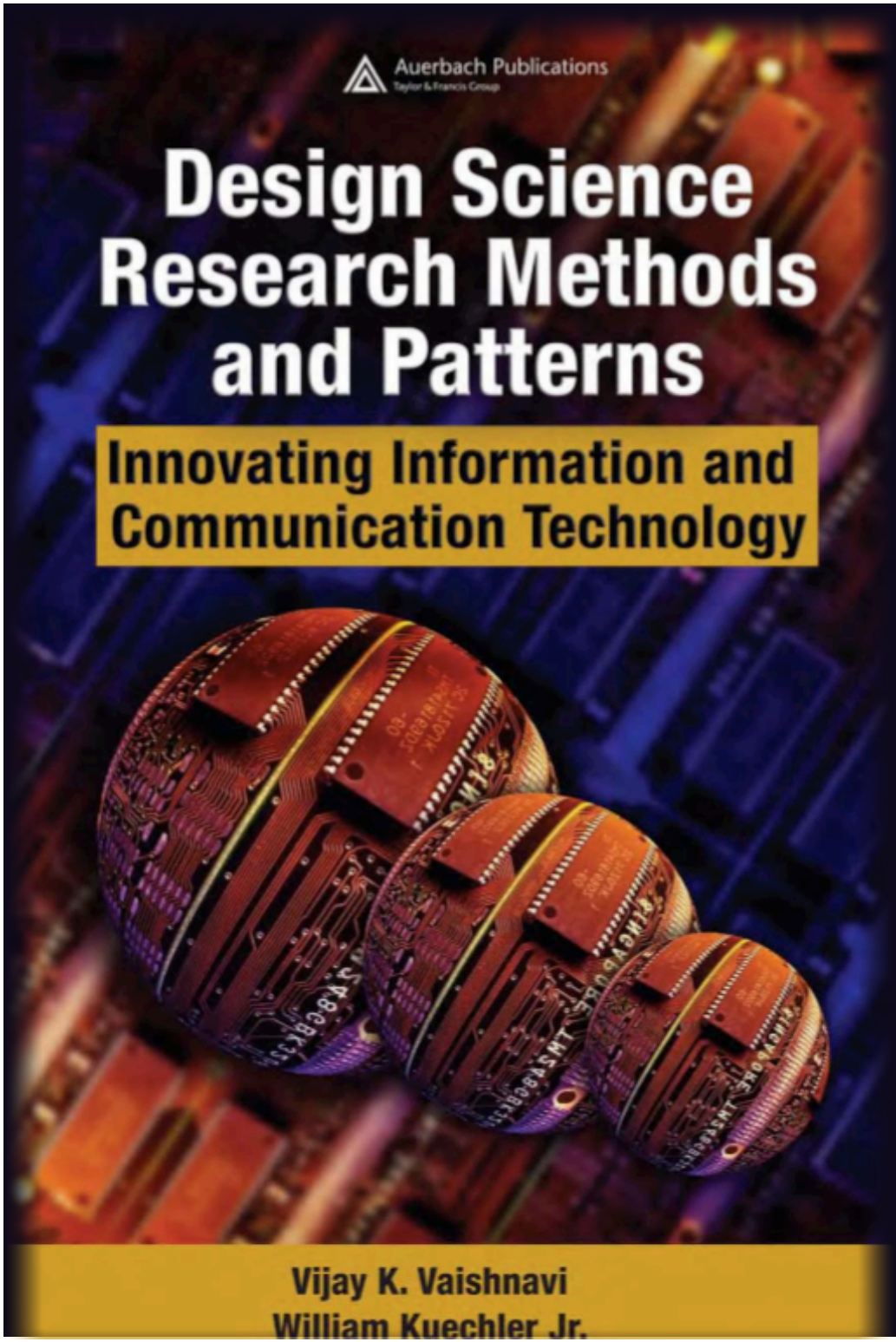
http://www.flickr.com/photos/rosepetal/2306185261/

part II - research question

part III - evaluation

1

design patterns


Auerbach Publications
Taylor & Francis Group
Design Science Research Methods and Patterns
Innovating Information and Communication Technology
Vijay K. Vaishnavi
William Kuechler Jr.

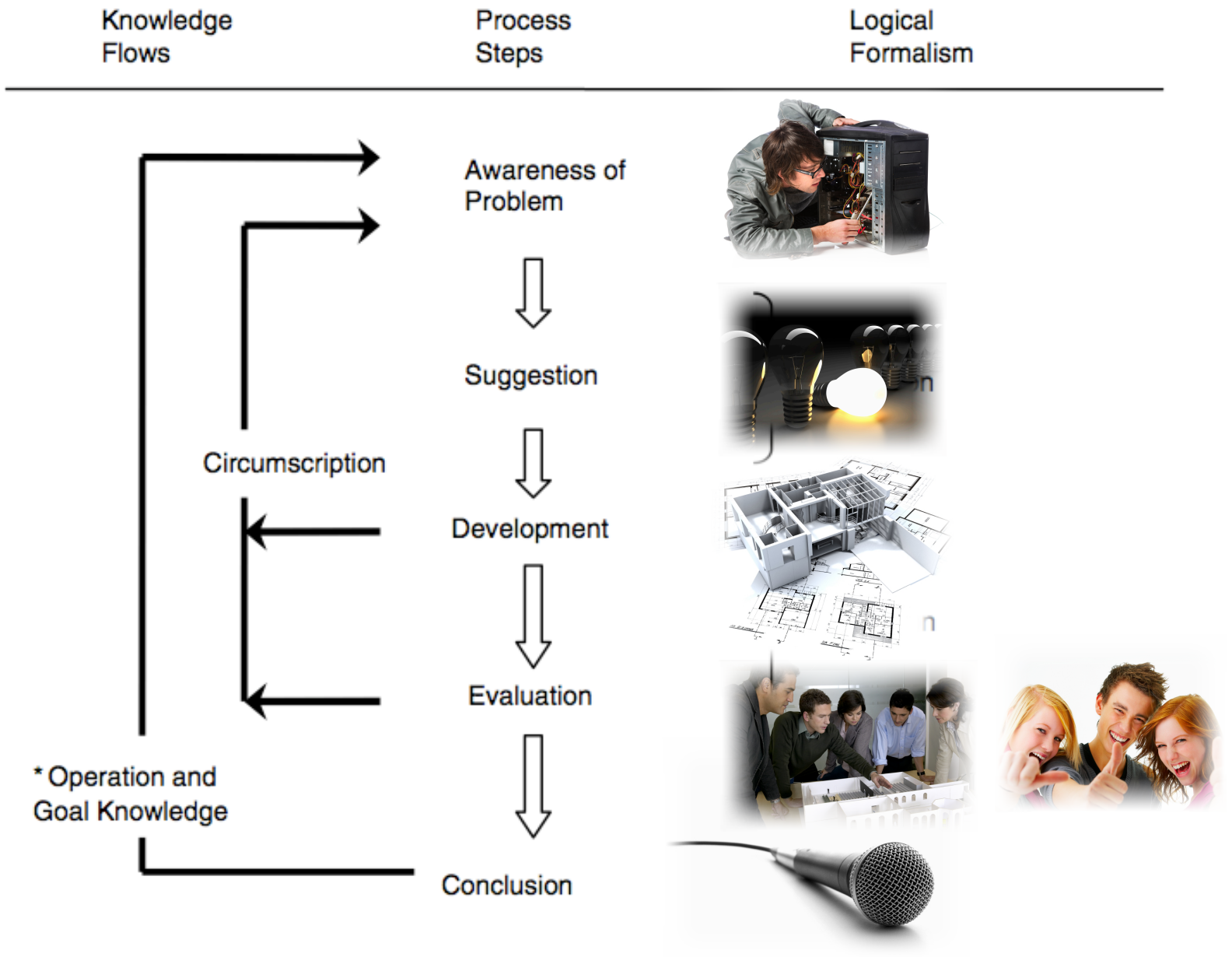
chapter 5

questions

what is the focus of the chapter and the main book idea?

using patterns ...

- to illuminate research practice
- as a means of communicating
- to describe aspects of the art of design science research



general design cycle (GDC)

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

pattern

general design cycle

pattern usage

questions

what is a pattern?

what could be its role in design research?


a solution to ...

a recurrent problem ...


within a specific context

pattern ...

a solution to a recurrent problem within a specific context

knowledge reuse of successful designs

more or less popular in design such as architecture, human-computer interaction, software engineering ...

> Pattern in architecture is the idea of capturing architectural design ideas as archetypal and reusable descriptions.

— Christopher Alexander's idea

pattern ...

> “ ... a communication technique to communicate a *way of building* structures ”

- [Alexander, 1964]

name

ranking

context

243 SITTING WALL**

picture

. . . if all is well, the outdoor areas are largely made up of positive spaces—POSITIVE OUTDOOR SPACES (106); in some fashion you have marked boundaries between gardens and streets, between terraces and gardens, between outdoor rooms and terraces, between play areas and gardens—GREEN STREETS (51), PEDESTRIAN STREET (100), HALF-HIDDEN GARDEN (111), HIERARCHY OF OPEN SPACE (114), PATH SHAPE (121), ACTIVITY POCKETS (124), PRIVATE TERRACE ON THE STREET (140), OUTDOOR ROOM (163), OPENING TO THE STREET (165), GALLERY SURROUND (166), GARDEN GROWING WILD (172). With this pattern, you can help these natural boundaries take on their proper character, by building walls, just low enough to sit on, and high enough to mark the boundaries.

If you have also marked the places where it makes sense to build seats—SEAT SPOTS (241), FRONT DOOR BENCH (242)—you can kill two birds with one stone by using the walls as seats which help enclose the outdoor space wherever its positive character is weakest.

problem

❖ ❖ ❖

In many places walls and fences between outdoor spaces are too high; but no boundary at all does injustice to the subtlety of the divisions between the spaces.

forces

Consider, for example, a garden on a quiet street. At least somewhere along the edge between the two there is a need for a seam, a place which unites the two, but does so without breaking down the fact that they are separate places. If there is a high wall or a hedge, then the people in the garden have no way of being connected to the street; the people in the street have no way of being connected to the garden. But if there is no barrier at all—then the division between the two is hard to maintain. Stray dogs can wander in and out at will; it is even uncomfortable to sit in the garden, because it is essentially like sitting in the street.

Alexander's patterns in architecture

[Borcher, 2001] Ashraf Gaffar, Daniel Sinnig 2003

The problem can only be solved by a kind of barrier which functions as a barrier which separates, and as a seam which joins, at the same time.

A low wall or balustrade, just at the right height for sitting, is perfect. It creates a barrier which separates. But because it invites people to sit on it—invites them to sit first with their legs on one side, then with their legs on top, then to swivel round still further to the other side, or to sit astride it—it also functions as a seam, which makes a positive connection between the two places.

Examples: A low wall with the children's sandbox on one side, circulation path on the other; low wall at the front of the garden, connecting the house to the public path; a sitting wall that is a retaining wall, with plants on one side, where people can sit close to the flowers and eat their lunch.

Ruskin describes a sitting wall he experienced:

Last summer I was lodging for a little while in a cottage in the country, and in front of my low window there were, first, some beds of daisies, then a row of gooseberry and currant bushes, and then a low wall about three feet above the ground, covered with stone-cress. Outside, a corn-field, with its green ears glistening in the sun, and a field path through it, just past the garden gate. From my window I could see every peasant of the village who passed that way, with basket on arm for market, or spade on shoulder for field. When I was inclined for society, I could lean over my wall, and talk to anybody; when I was inclined for science, I could botanize all along the top of my wall—there were four species of stone-cress alone growing on it; and when I was inclined for exercise, I could jump over my wall, backwards and forwards. That's the sort of fence to have in a Christian country; not a thing which you can't walk inside of without making yourself look like a wild beast, nor look at out of your window in the morning without expecting to see somebody impaled upon it in the night. (John Ruskin, *The Two Paths*, New York: Everyman's Library, 1907, p. 203.)

Therefore:

Surround any natural outdoor area, and make minor boundaries between outdoor areas with low walls, about 16 inches high, and wide enough to sit on, at least 12 inches wide.

examples

diagram

243 SITTING WALL

✣ ✣ ✣

Place the walls to coincide with natural seat spots, so that extra benches are not necessary—SEAT SPOTS (241); make them of brick or tile, if possible—SOFT TILE AND BRICK (248); if they separate two areas of slightly different height, pierce them with holes to make them balustrades—ORNAMENT (249). Where they are in the sun, and can be large enough, plant flowers in them or against them—RAISED FLOWERS (245). . . .

references

solution

Alexander's patterns in architecture

[Borcher, 2001] Ashraf Gaffar, Daniel Sinnig 2003

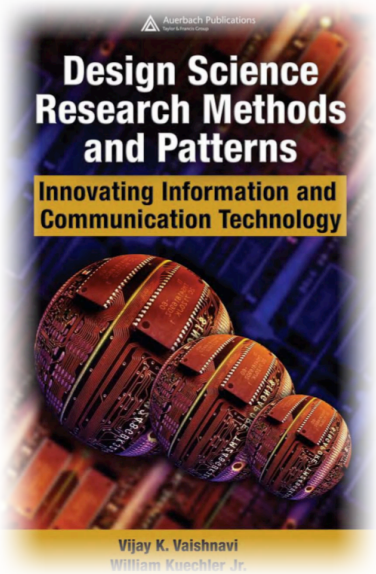
use of patterns

- capture and description
  define key characteristics of a situation or event in a context-sensitive way
- generalization
  generalize across varying situations
- prescription
  give prescriptive guidelines for common problems
- rhetoric
  create the vocabulary for a lingua franca, a common language, between designers and users
- prediction
  judge potential consequences of design changes to an existing system, by following ramifications through the pattern network

[Borcher, 2001] Ashraf Gaffar, Daniel Sinnig 2003

use of patterns in design research

- a formalized way of recording experience ...
- [which] would enable the written ...
  as opposed to the verbal and imitative
- communication of concepts, techniques and interrelationships ...
- that make up research praxis



[Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

pattern canvas

intent
context and applicability
description
consequences
example
related patterns
references

sample

problem formulation

intent	identify a specific research problem along the interesting research questions and issues
context and applicability	one has identified a research domain; one may have identified a set of problems in the research domain
description	- literature search, - identification of goals, - understanding the research community ...
consequences	should lead to a research problem of interest to the research community
examples	Purao, S., Storey, V., Han, T. (2003) Improving analysis pattern reuse in conceptual design. ISR, 14(3): 269-290 and ...

pattern

general design cycle

pattern usage

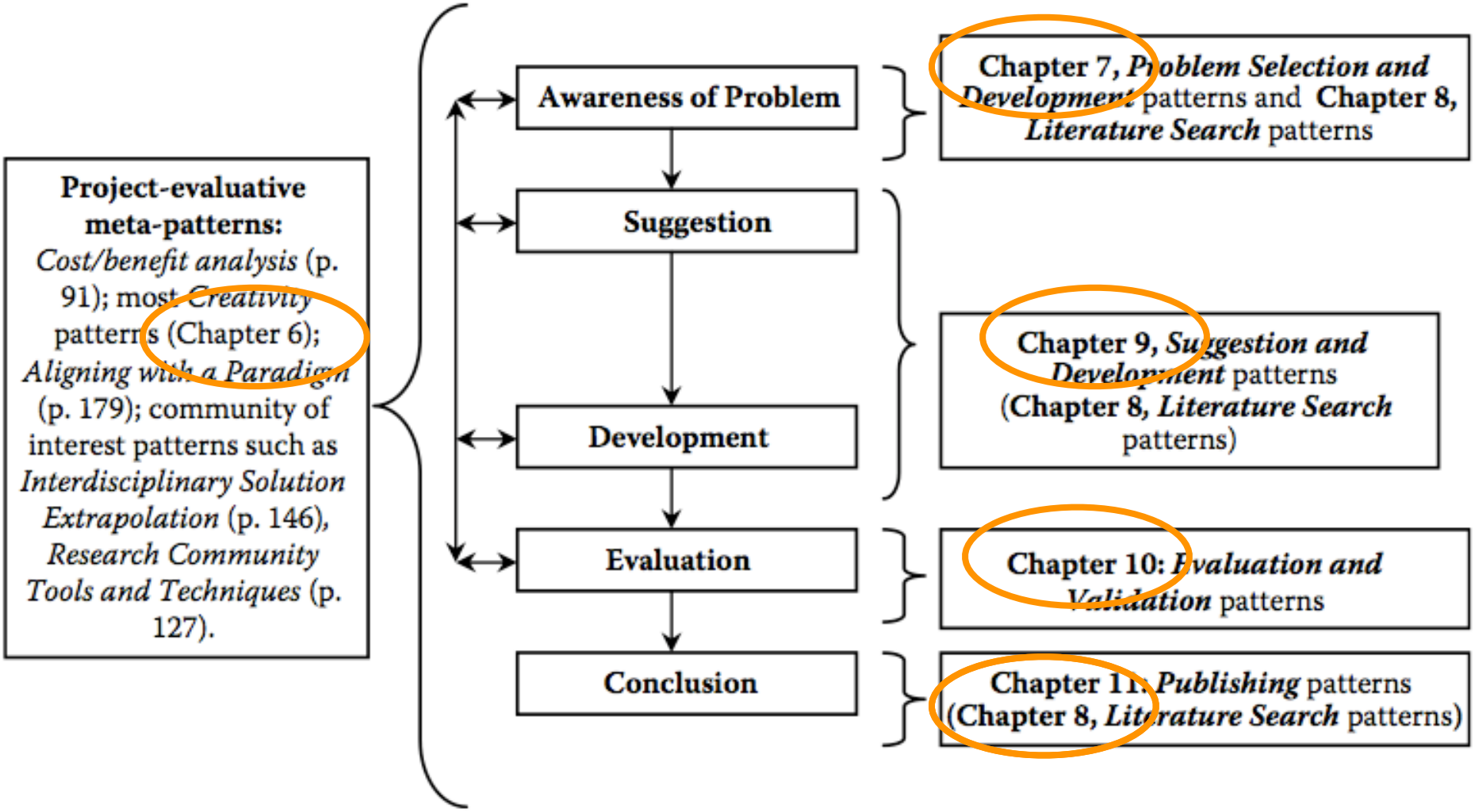
questions

how patterns could be applied to the major activities of the design research?

how they could be categorized?

categorization of patterns

6. creativity
7. problem selection and development
8. literature search
9. suggestion and development
10. evaluation and validation
11. publishing



patterns at various phases of the general design cycle

[Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

part II - research proposal

2

research question

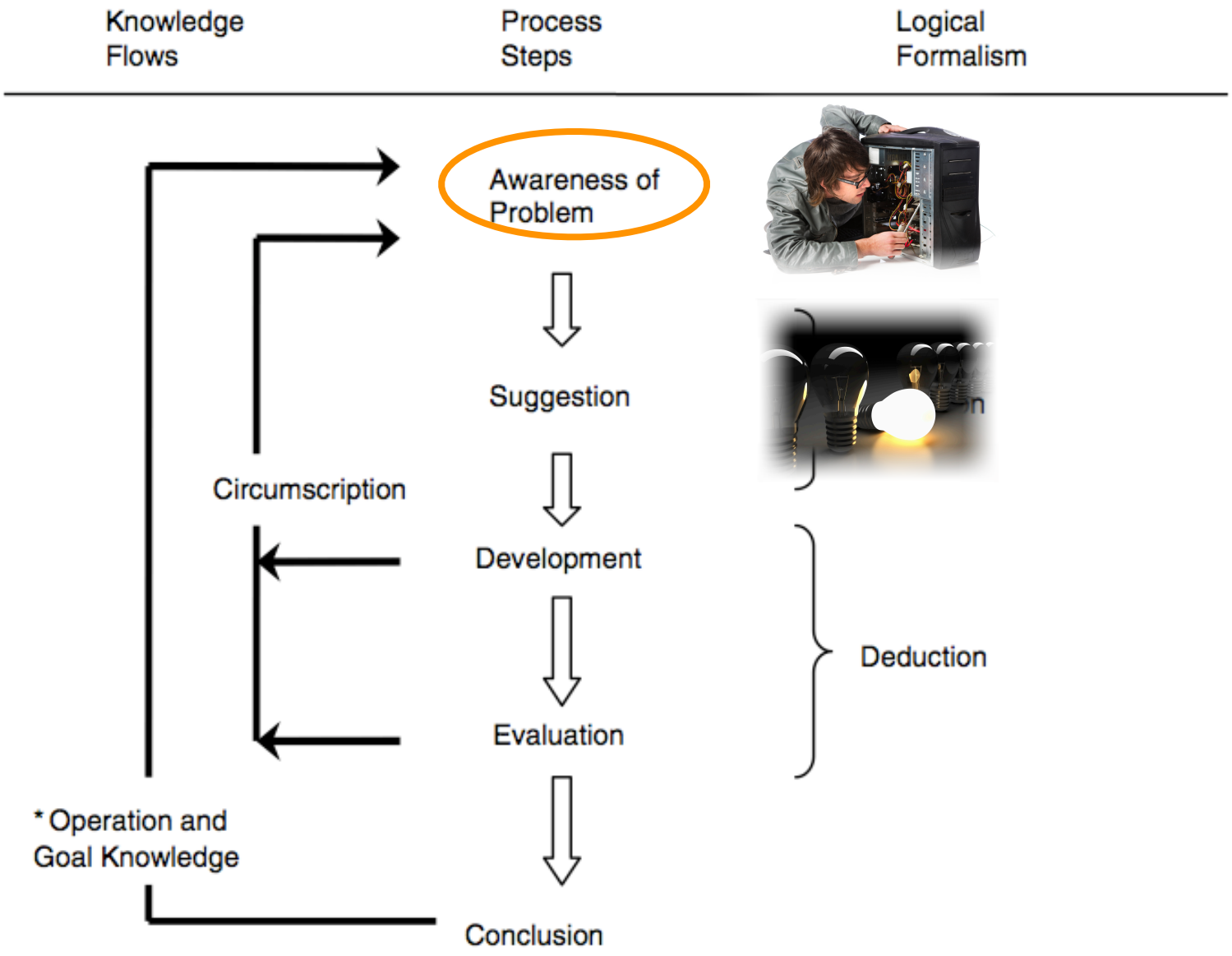
question

how to write a research question ...

which patterns?

which factors in selecting the research topics?

and then the research proposal ...



general design cycle (GDC)

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

research question

factors

research proposal

pre-awareness of problem

- search for *interesting* problems to solve and their explication *published*
- become familiar with the research community
- patterns:
  - *aligning with a paradigm*
  - *research conversation*
  - *research domain identification*

awareness of problem

- scope the research problem
  command and control in critical complex environment (nuclear reactors)

- patterns:

  - *problem area identification*
  - *problem formulation*
  - *research conversation*

Patterns Utilized	*Actions Generated*
Aligning with a Paradigm (p. 179); Research Conversation (p. 88); and Research Domain Identification (p. 84)	Using these patterns, a design research opportunity emerged from a serendipitous site visit to an interesting (of and about designed artifacts) site.
Problem Area Identification (p. 86); Complex System Analysis (p. 107); Problem Formulation (p. 87); Understanding Research Community (p. 112); Research Conversation (p. 88); Research Domain Identification (p. 84)	Using these patterns, opportunities for IT-related improvement of the operation of the site were investigated and a preliminary problem determined. The appropriate research community — complex control systems design — was identified.
Industry and Practice Awareness (p. 116); Research Conversation (p. 88); Solution and Scope Mismatch (p. 93); Being Visionary (p. 95); Brainstorming (p. 79); Problem Formulation (p. 87)	When applied to what had been discovered of the problem domain given the effort expended to date, these patterns suggested that the domain was ill defined, and simply determining a properly scoped ("do-able") problem would be challenging. This phase of the project was revisited after developing a preliminary solution in the Suggestion phase and a more tightly defined research problem formulated.
Bridging Research Communities (p. 98); Research Domain Identification (p. 84); Understanding Research Community (p. 112); Research Conversation (p. 88)	Three distinct but interrelated research communities were identified, and the literature for the research communities was revisited in a focused manner via the application of these patterns.

pattern application during the "awareness of problem" phase search

[Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

problem area identification

intent	identify a general set of research questions or problems that are of interest to oneself or to the relevant paradigmatic community
context and applicability	one has identified a research domain in which one wants to conduct research but one does not yet have a research topic
description	1. familiarize with the research domain 2. understand the community 3. using a framework to understand the work conducted in this area
consequences	a set of problems and issues of interest to the research community and to the practitioner community
examples	...

problem formulation

intent	identify a specific research problem along the interesting research questions and issues
context and applicability	one has identified a research domain; one may have identified a set of problems in the research domain
description	- literature search, - identification of goals, - understanding the research community ...
consequences	should lead to a research problem of interest to the research community
examples	Purao, S., Storey, V., Han, T. (2003) Improving analysis pattern reuse in conceptual design. ISR, 14(3): 269-290 and ...

cost-benefit analysis META

intent	determine if the planned resource is justified by the expected research benefits
context and applicability	one is planning to commit to a large amount of resources for a research project
description	- analyze and estimate the expected cost and benefits - explore alternative less-expensive strategies - develop a detailed plan with milestones ...
consequences	will help explore all alternatives before plunging into a strategy for conducting research
examples	...

understanding research community

intent	understand how the community organizes its intellectual structure and gain acceptance by the community
context and applicability	one is new to the research community
description	- use literature - know intellectual boundaries - retain creativeness to influence the community
consequences	help in one's assimilation into the community
examples	Choobineh, J, Lo, A. (2005) Case-based system for database design. JMIS 21(3): 281-314

research question
factors
research proposal

Table 1. Factors in Selecting Research Topics

Factors in Finding Ideas to Consider	Factors in Selecting Ideas to Pursue
• Previous Research	• Study Fundamental Issues
• Current Practice	• Simplify Complex Theories
• Future Practice	• Study Anomalies
• Personal Experience	• Create News Value
• Other Disciplines	• Fit with Current and Future Research
• Resources	

The research question should be ...

- clear
- focused
- complex
- evocative
- relevant
- researchable


clear

the research question should be clear

- Unclear:
  Why are social networking sites harmful?

- Clear:
  How are online users experiencing or addressing privacy issues on such social networking sites as MySpace and Facebook?

http://writingcenter.gmu.edu/resources-template.php?id=59


focus

the research question should be focus

- Unfocused:
  What is the effect on the environment from global warming?

- Focused:
  How is glacial melting affecting penguins in the Arctic Circle?

http://writingcenter.gmu.edu/resources-template.php?id=59


Le shampoing d'eau de mer aux st.Jacques et Wasabi
complex

the research question should be complex

- Too simple:
  How are doctors addressing diabetes in the U.S.?

- Appropriately Complex:
  What are common traits of those suffering from diabetes in America, and how can these commonalities be used to aid the medical community in prevention of the disease?

http://writingcenter.gmu.edu/resources-template.php?id=59


evocative

the research question should be evocative

- Make it timely
- **Frame it as a paradox**
- Take a distinctive approach

http://globetrotter.berkeley.edu/DissPropWorkshop/nuts&bolts/question.html

Frame it as a paradox

- *why have indigenous organizations in Bolivia markedly declined*
  while the number and quantity of funding sources has increased?

- *why have violent conflicts over forest resources increased in the last ten years*
  while the very people involved in these conflicts have become less and less dependent on forest resources for their livelihoods?

relevant

The research question should be relevant

- Fill in the missing piece
- Make connections

http://globetrotter.berkeley.edu/DissPropWorkshop/nuts&bolts/question.html


researchable

The research question should be researchable

- How long will the research take to carry out?
- Do you have the appropriate background to carry out the research?
- If I can't complete this project well, can I break it down and address the most important component?

http://globetrotter.berkeley.edu/DissPropWorkshop/nuts&bolts/question.html

choosing the topic ...

“… when choosing a topic, don't make it your life's work. The idea is to have a bounded topic, one that you can finish in a reasonable time.”

Van Slyke et al. (2002) Experts’ Advice to Information Systems Doctoral Students. Comm. CAIS, 12 : 469-478

for your research ...

title

Main research question

First sub-question

Second sub-question

Third sub-question

research question

factors

research proposal:

suggestions, development, evaluation & communication

part III - evaluation and ...


... validation patterns
http://www.livingneighborhoods.org/pics/farmerchris2004.jpg

3

evaluation patterns

question

what is evaluation?

evaluation ...

“ systematic determination of merit, worth, and significance of something or someone using criteria against a set of standards, often used to characterize and appraise subjects of interest in a wide range of human enterprises ... ”

wikipedia (access May 2009)

evaluation in design science research ...

> “ ... is concerned with evaluation of design science output including theory and artifacts ”

- Jan Pries-Heje et al.

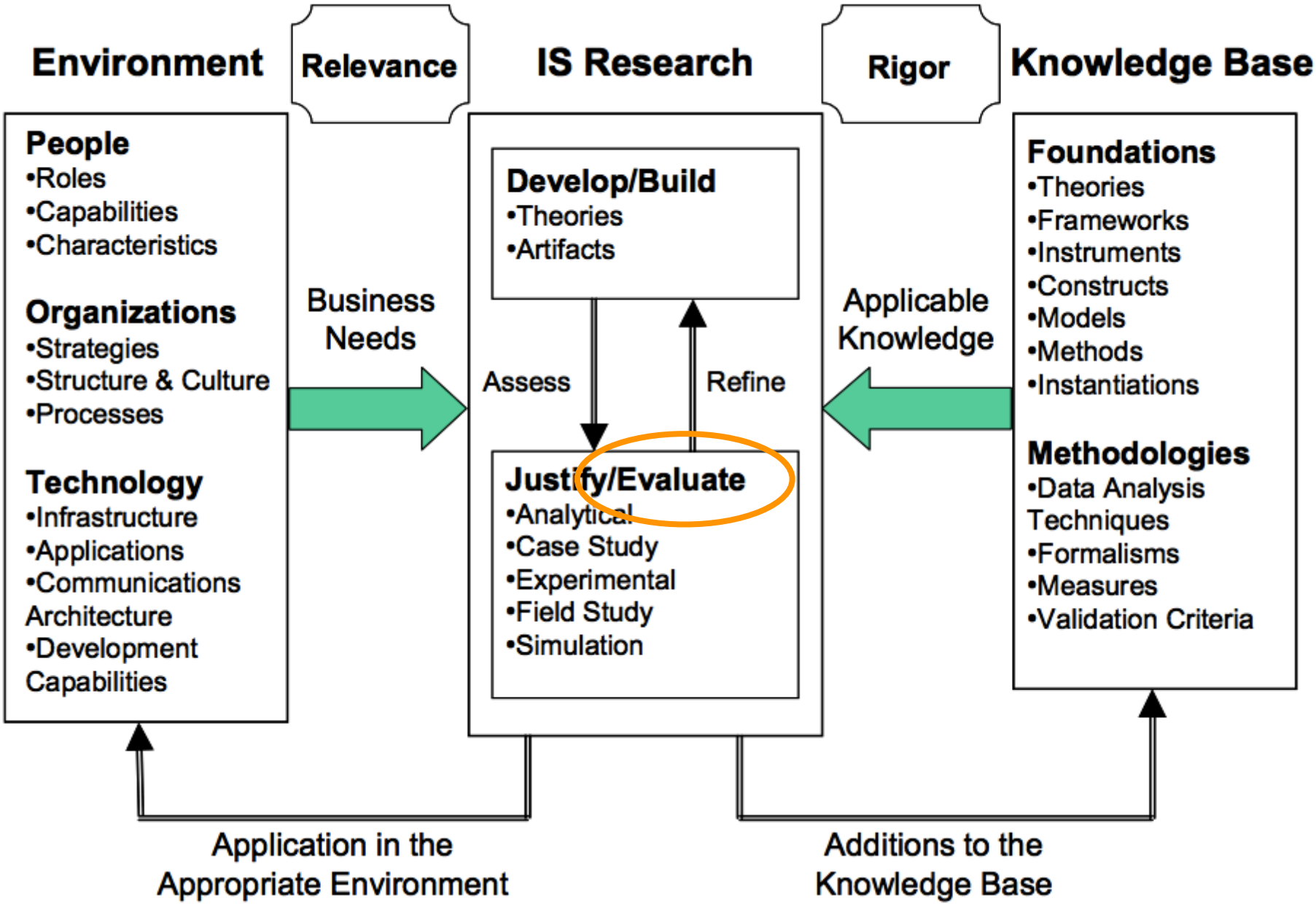


Figure 2. Information systems research framework

[Hevner et al., 2004]

question

what are the design evaluation methods?

1. Observational	Case Study: Study artifact in depth in business environment
	Field Study: Monitor use of artifact in multiple projects
2. Analytical	Static Analysis: Examine structure of artifact for static qualities (e.g., complexity)
	Architecture Analysis: Study fit of artifact into technical IS architecture
	Optimization: Demonstrate inherent optimal properties of artifact or provide optimality bounds on artifact behavior
	Dynamic Analysis: Study artifact in use for dynamic qualities (e.g., performance)
3. Experimental	Controlled Experiment: Study artifact in controlled environment for qualities (e.g., usability)
	Simulation – Execute artifact with artificial data
4. Testing	Functional (Black Box) Testing: Execute artifact interfaces to discover failures and identify defects
	Structural (White Box) Testing: Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation
5. Descriptive	Informed Argument: Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility
	Scenarios: Construct detailed scenarios around the artifact to demonstrate its utility

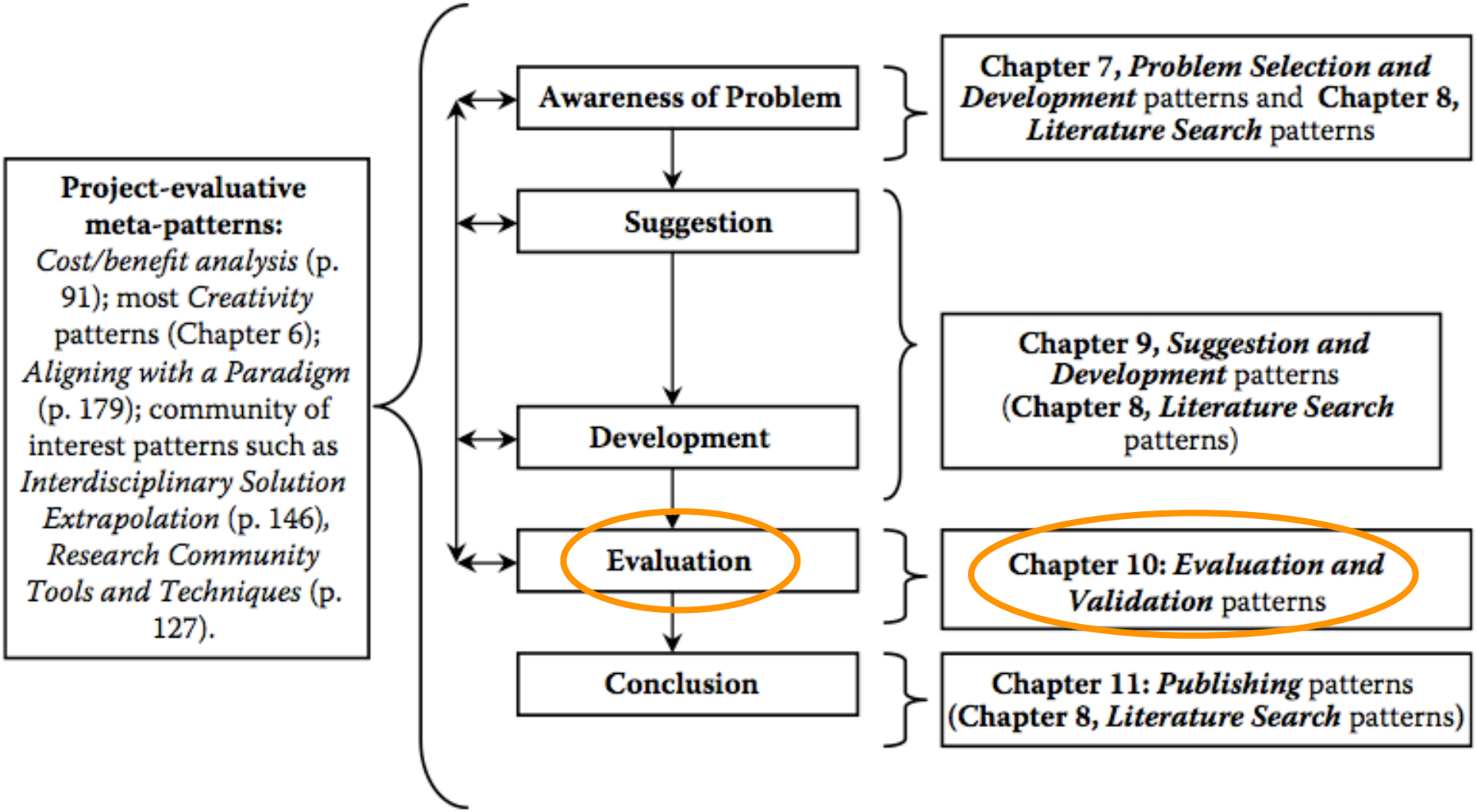
Design evaluation methods

reminder

[Hevner et al., 2004]

evaluation and validation patterns

strategies for evaluation



patterns at various phases of the general design cycle (GDC)

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

question

which patterns provide vehicles for evaluation and validation?

evaluation and validation

- demonstration
- experimentation
- simulation
- using metrics
- benchmarking
- logical reasoning
- mathematical proofs

analysis

demonstration

intent	demonstrate that the solution is realizable and valid in predefined situations.
context and applicability	the problem or the solution is such that it is not possible to mathematically prove the correctness of the solution.
description	1. construct the solution; 2. demonstrate the solution is reasonable for a set of predefined situations.
consequences	the demonstration may show the inadequacies of the solution. [...] it may show that the solution is feasible and acceptable
examples	...

experimentation

intent	use experimentation to validate or reject a set of hypotheses associated with the claims about the solution
context and applicability	one has developed a set of hypotheses related to the claims about the solution. One cannot prove these hypotheses mathematically or logically.
description	1. hypothetical/deductive 2. prototyping 3. case-based 4. historical > see table
consequences	helps in establishing results associated with the solution in situations where collecting and analyzing data is the only feasible method of validation
examples	...

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

Hypothetical/ Deductive	*Prototyping (Hermeneutical/ Inductive)*	*Case-Based*	*Historical*
Use intuition, results of past experiments, and a literature review to build the system with the intent of testing a set of hypotheses. Testing the system under varying environments is the experiment. *Collect the experimental data and analyze it to accept or reject the hypotheses.*	Build the system and the associated hypotheses inductively from prototyping and its documentation without any prior commitment. Developing the system is the experiment. *Analyze the prototyping documentation to qualitatively accept or reject the hypotheses.*	Build a prototype based on an initial set of hypotheses. As the prototyping progresses, one will get a deeper knowledge of the problem. Use this knowledge to modify the hypotheses and the prototype guided by the revised hypotheses. Developing the prototype is the experiment. *Use documentary evidence from the prototype to accept or reject the hypotheses.*	Develop a solution and hypotheses from previously developed systems. Observing past systems is the experiment. *Accept or reject hypotheses based on cumulative data from past systems.*

experiment types and corresponding method of hypotheses testing

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

simulation

intent	use simulation to evaluate and validate one's solution to the research problem.
context and applicability	the evaluation in the real-life setting is either not feasible or costly [...] but can be accurately modeled on a computer.
description	1. develop a conceptual model 2. develop an initial test data that can exercice the model 3. select a simulation package 4. run the simulation program to test suite 5. argue the testing is representative of the real-life situation
consequences	provides a reasonable and cost-effective way of evaluating and validating a solution
examples	...

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

using metrics

intent	use established metrics to aid validation of one's solution to the research problem.
context and applicability	established metrics exist in the literature that one can use to evaluate the performance of one's solution
description	1. determine whether or not there exist established metrics that are appropriate to measure the performance 2. analyze or measure the solution using the chosen metrics 3. show that the solution has the hypothesized performance according to the chosen metric
consequences	allows one to validate the solution in a way that is already accepted by the research community
examples	...

benchmarking

intent	use an available benchmark to show that one's solution has reasonable performance or is better than some other available solution.
context and applicability	there is no established metric available that one can use to measure the performance of one's solution
description	1. identify the benchmark that one can use to evaluate the solution 2. use the benchmark to show the merit of the solution
consequences	benchmarking provides a vehicle for objective evaluation of a solution or comparison of different solutions
examples	...

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

logical reasoning

intent	use logical reasoning to argue the validity of the solution.
context and applicability	The constructs and assumptions are precise enough that a logical argument can be built for the hypothesized claims about the solution
description	1. identify "axioms" related to the research problem 2. identify "deduction rules" 3. build a logical path from the "axioms" to the hypotheses using the deduction rules
consequences	more or less formal argumentation
examples	...

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

mathematical proofs

intent	prove mathematically the claims being made about the solution that one has developed for the research problem.
context and applicability	the essential aspects of the problem and the solution can be expressed formally in a closed logical system
description	1. express hypothesized claims about the solution 2. cast the claims as theorem in a well-defined formal logical system 3. prove the claims theorem
consequences	provides the strongest form of validation of the claims one has made about the solution
examples	...

adapted from [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns*

evaluation and validation patterns

strategies for evaluation

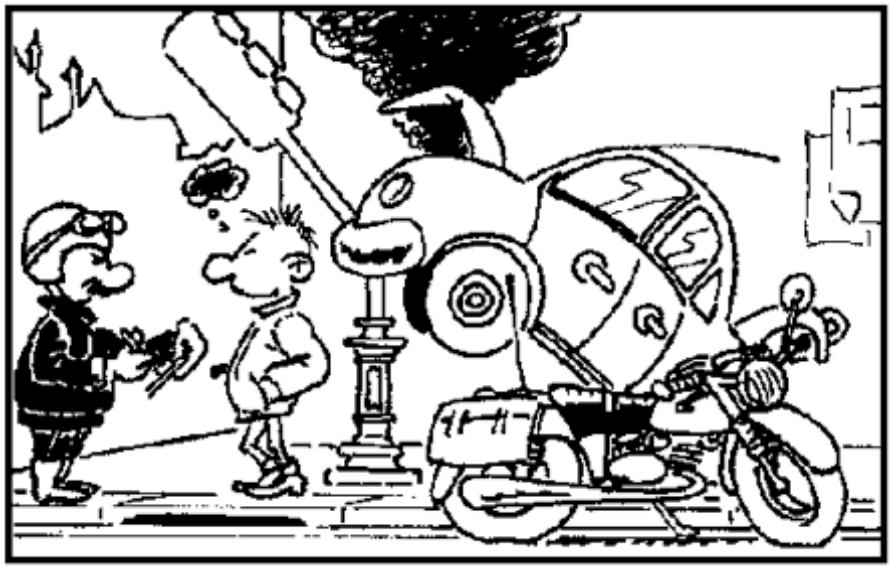
Strategies for design science research evaluation

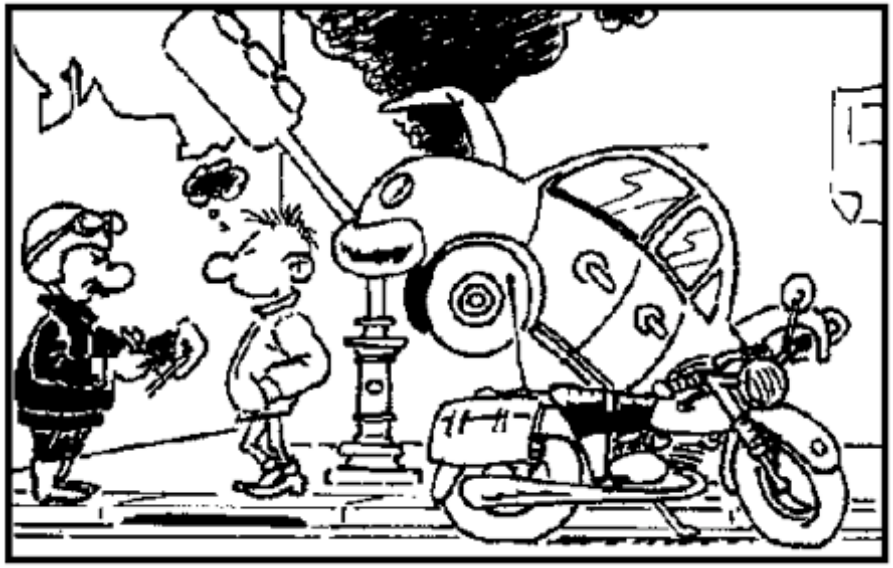
Jan Pries-Heje, Richard Baskerville and John Venable

In Proceedings, 16th European Conference on Information Systems, Galway (2008)

- see also [Vaishnavi and Kuechler, 2007] *Design science research methods and patterns* ch. 10

the “7 errors” game ...





find the error ...

detect an error in the paper

find the error ...

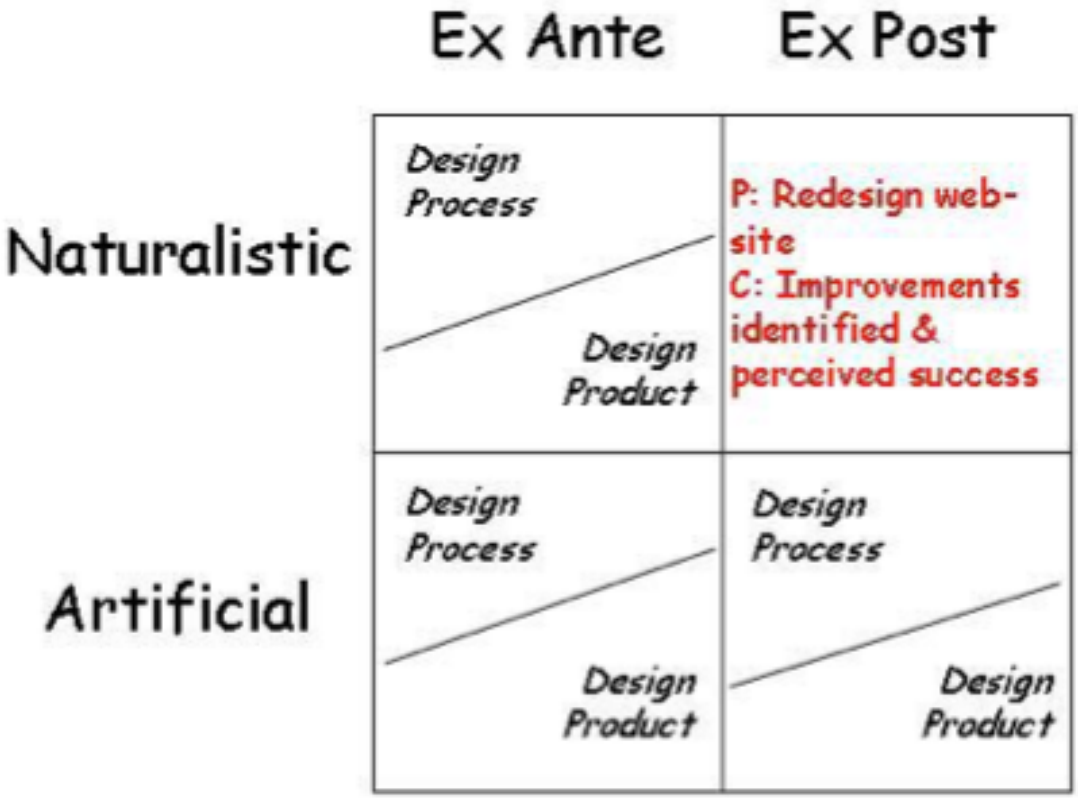


Figure 3. An ex post artificial evaluation strategy (Bell et al., 2007)

Figure 4. An ex post naturalistic strategy (Albert et al., 2004).

find the error ...

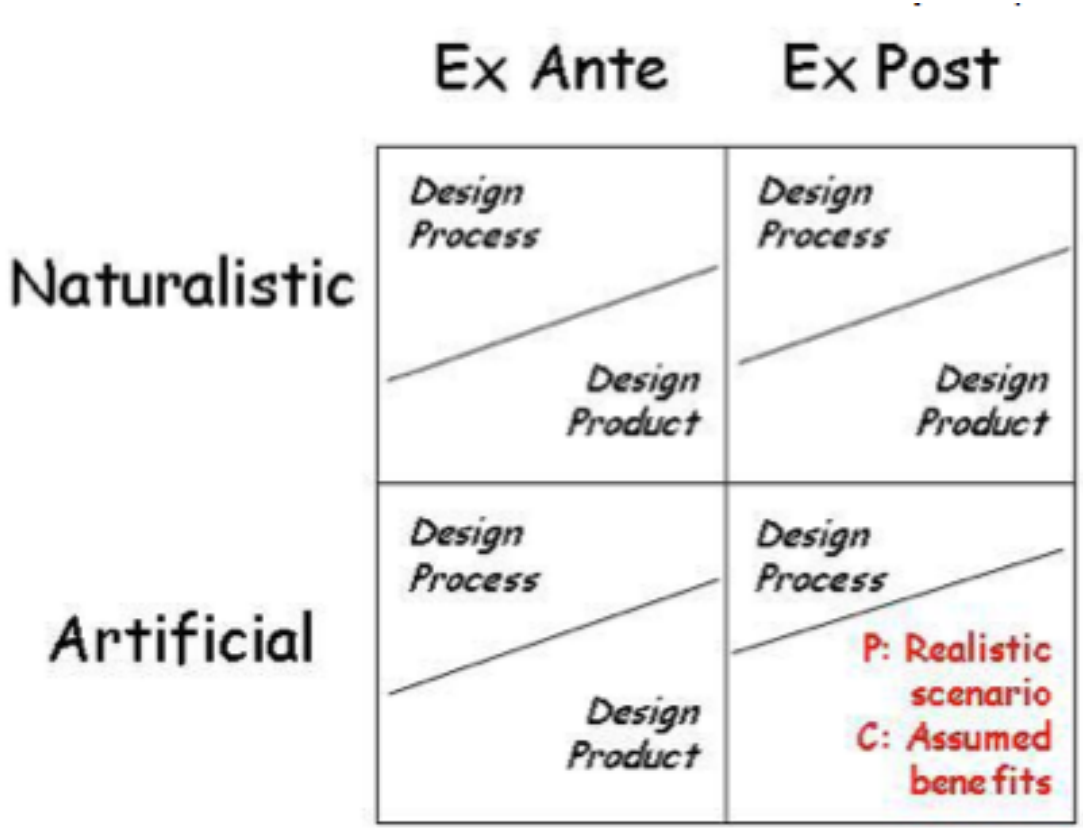


Figure 4. An ex post naturalistic strategy (Albert et al., 2004).

Figure 3. An ex post artificial evaluation strategy (Bell et al., 2007)

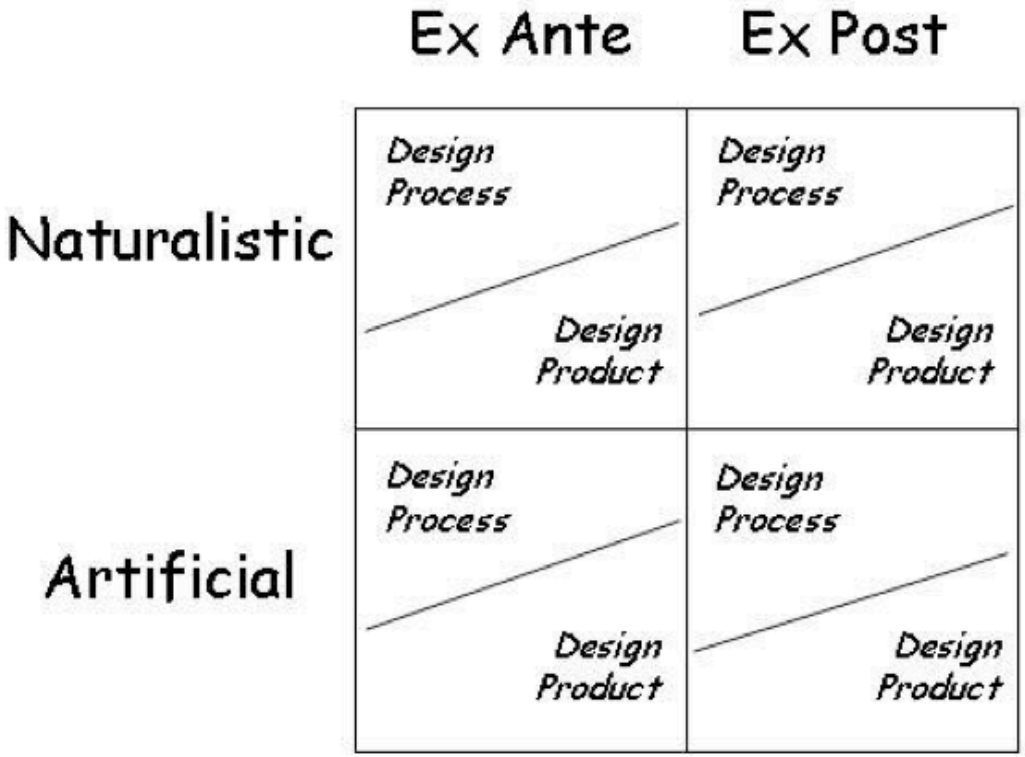
questions

what is the focus of the article?

design science research evaluation

- broader ranges of evaluation strategies
- a strategic framework
  - ex-ante & ex-post orientations
  - naturalistic & artificial settings

strategic evaluation framework



[Pries-Heje et al., 2008]

question

what is the difference between ex ante and ex post evaluation?


ex-ante orientation

ex ante evaluation

- whether or not to acquire or develop a technology
  - cost benefit analysis
- the artifact is evaluated on the basis of its design specifications
- fundamental measures (metrics), composite approach, meta-approaches (context)
- positivist or hermeneutic application

economic


R.I.P.
ex-post orientation

ex post evaluation

- real or abstract setting
- automatic or human-based (opinion) method for computing quality measures
- “context, content, and process” (CCP model)

question

what is the difference between naturalistic and artificial evaluation?


naturalistic setting

naturalistic evaluation

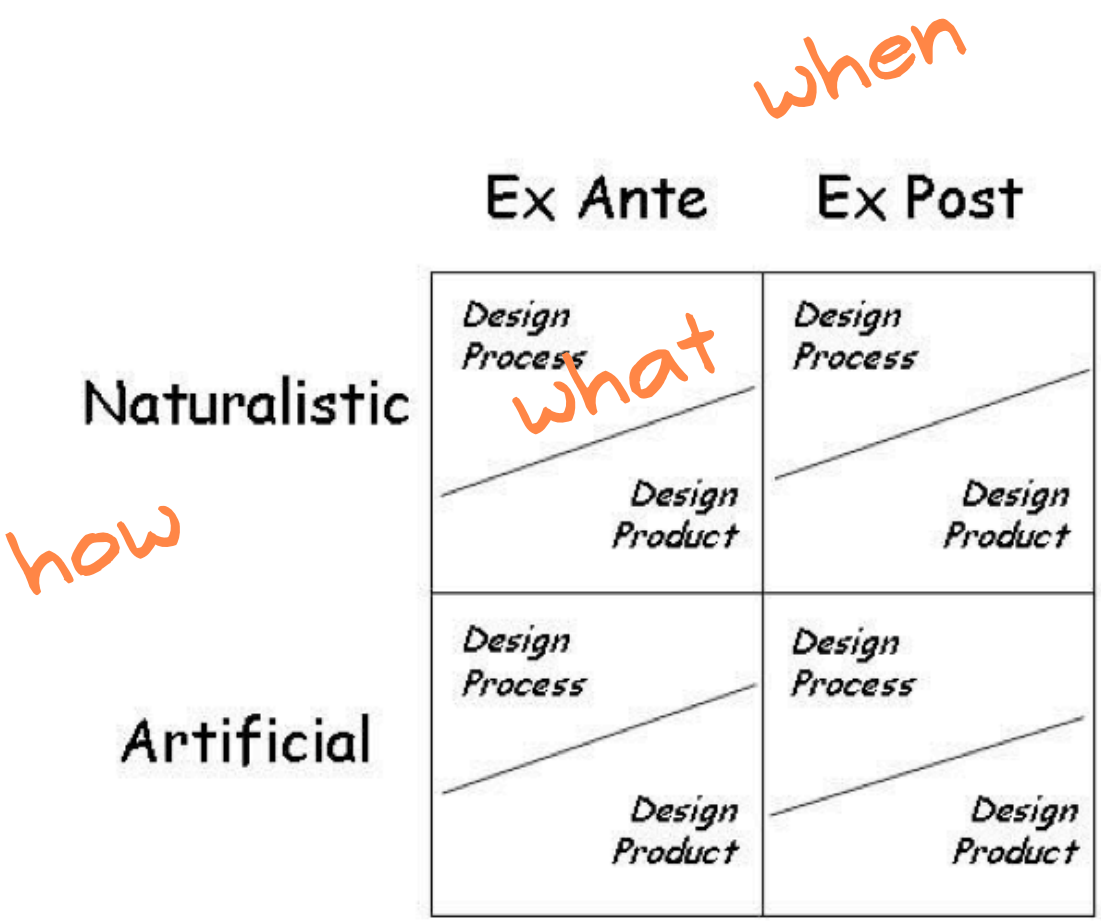
- explores the performance of a solution in its real environment
- *“the real proof of the pudding:*
  real users using real systems to solve real problems”
- embraces all the complexities of human practices in real organizations, always empirical, may be interpretive or positivist
- includes case studies, field studies, ethnography, phenomenology, hermeneutic methods, and action research

artificial settings

artificial evaluation

- in a contrived and non-realistic way
- nearly always positivist, being used to test design hypotheses
- includes laboratory experiments, field experiments, simulations, criteria-based analysis, theoretical arguments, mathematical proofs
- "*unreal users, unreal systems, unreal problems*"

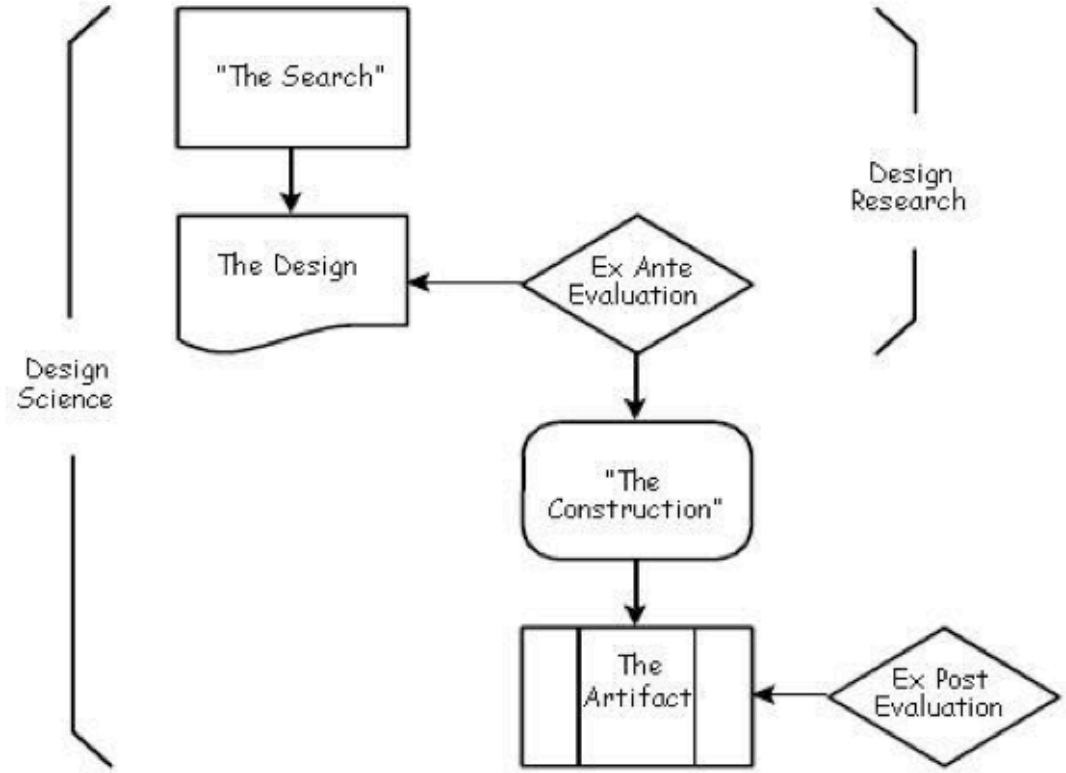
strategic evaluation framework



[Pries-Heje et al., 2008]

question

how to apply the strategic framework normatively?



ex ante versus ex post in design science research

[Pries-Heje et al., 2008]

evaluation measures

- quality of design product and design process
- quality criteria
- PRODUCT
  quality model such as ISO 9126
- PROCESS
  process-based quality

question

how to apply the strategic framework descriptively?

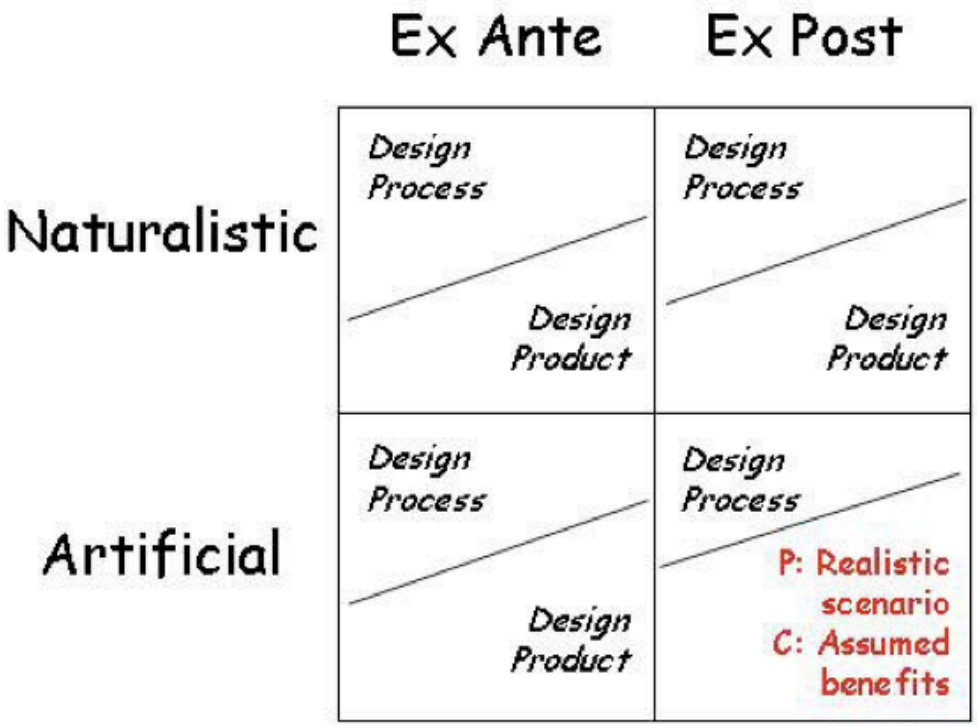
evaluation questions

- what is actually evaluated?
  design product (IT artefact) or process (IT development method)

- how it is being evaluated?
  naturalistically or artificially

- when was it evaluated?
  ex ante or ex post


DO IT



example

An ex-post artificial evaluation strategy [Bell et al., 2007]

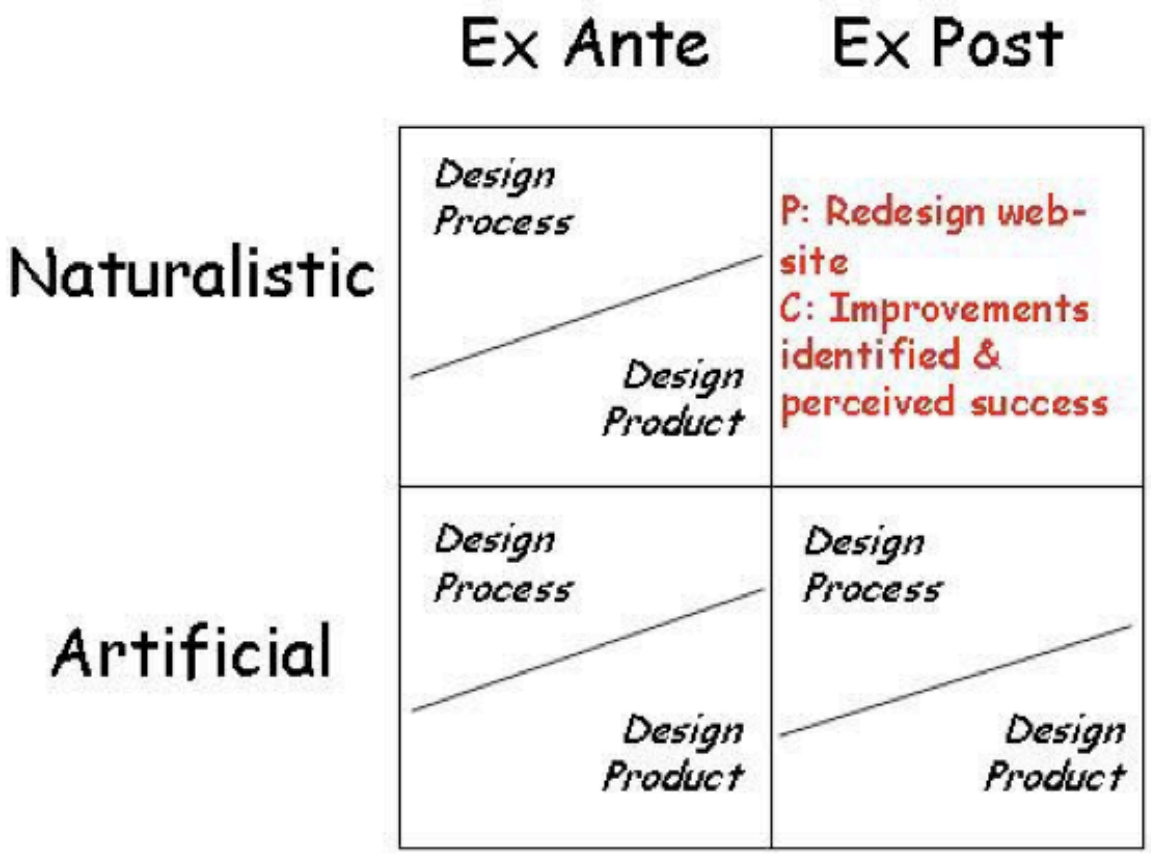
[Pries-Heje et al., 2008]

what	the framework for deriving semantic business processes from syntactic web services. The result is a design artefact than in itself is a process of how to derive semantics from syntax
how	an artificial evaluation in which the framework was enacted against a scenario " designed on the basis of previously developed services" (simulated pilot-project) ...
when	evaluated ex post, after the design artifact was developed

example

An ex-post artificial evaluation strategy [Bell et al., 2007]

[Pries-Heje et al., 2008]



example

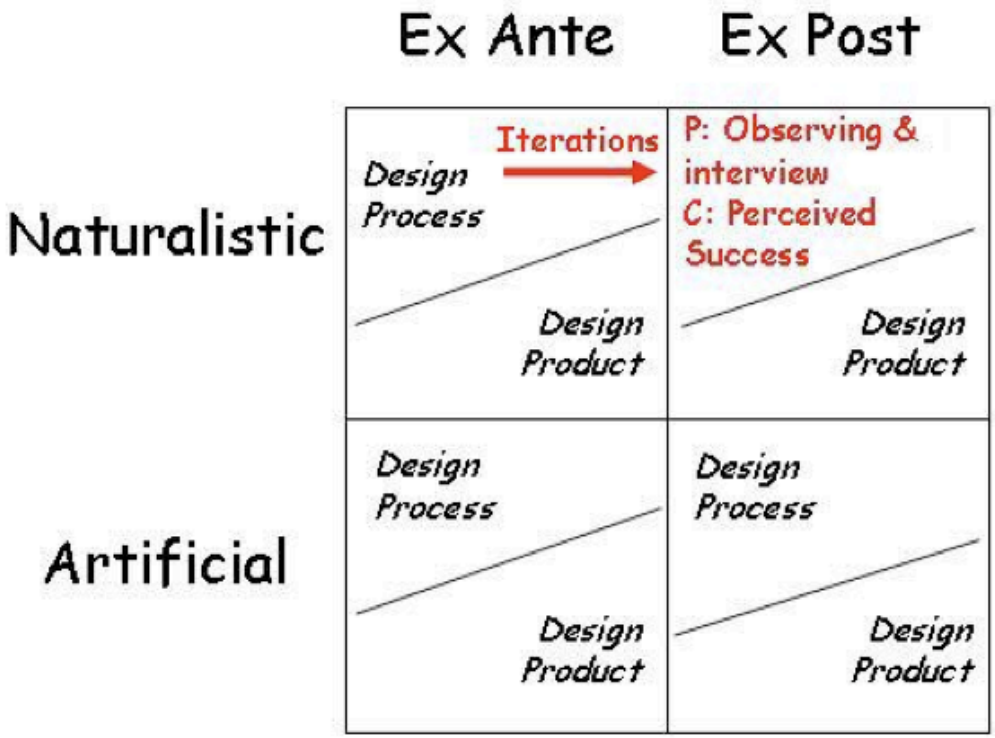
An ex-post naturalistic evaluation strategy [Albert et al., 2004]

[Pries-Heje et al., 2008]

what	both the web-site development (a design process) and the web-site management (a design product, albeit a process-oriented one) parts of GIST
how	a naturalistic evaluation is described in which an existing web-site in a Fortune 50 company was assessed focusing on identifying improvements. Thus it was conducted using a real system in a real organization facing real problems
when	evaluated ex post, after the design artifact was developed

example

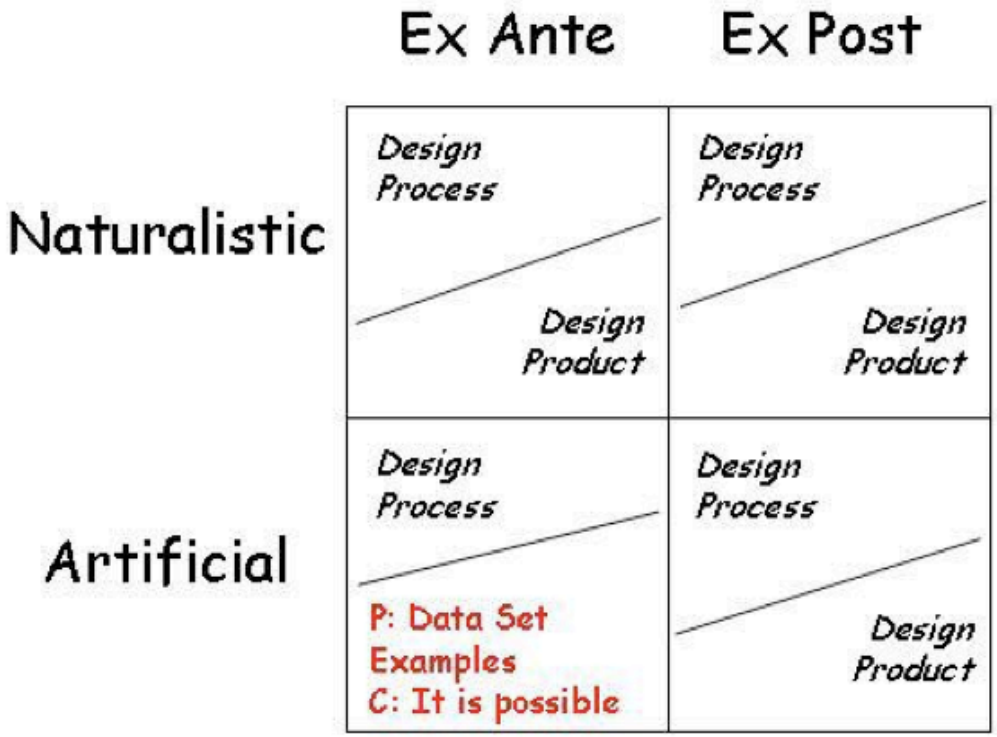
An ex-post naturalistic evaluation strategy [Albert et al., 2004]



example

An ex-ante & ex-post naturalistic evaluation strategy [Arnott, 2006]

[Pries-Heje et al., 2008]



example

An ex-ante artificial evaluation strategy [Zhao et al., 2000]

[Pries-Heje et al., 2008]

next

A new approach of innovative design: an introduction to C-K theory

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Armand Hatchuel and Benoît Weil

Proceedings of the international conference on engineering design (2003): 109–124.

▸(Ondrus and Pigneur, 2009) *C-K Design Theory for Information Systems Research*