Design Science Methodology
192320820

Winter 2015 - 2016
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0. Introduction

0.1 Goal of the course

Goal of the course

- Improve some of your problem-solving capability
  - Improve your capability to **justify** your solution
  - Help you **structure** your Master’s thesis

- Not a creativity course

Reality check

- What kind of problems?
  - http://essay.utwente.nl/view/programme/60025.html
  - http://essay.utwente.nl/view/programme/60300.html

Two kinds of research problems

- (1) Design problems
  - *Improve something, design something , how-to-do something*
  - Problem, design of a treatment, validation of the treatment
  - **Design cycle**
  - Utility is the goal
  - Knowledge is a side-effect
  - ``Technical research problems’’

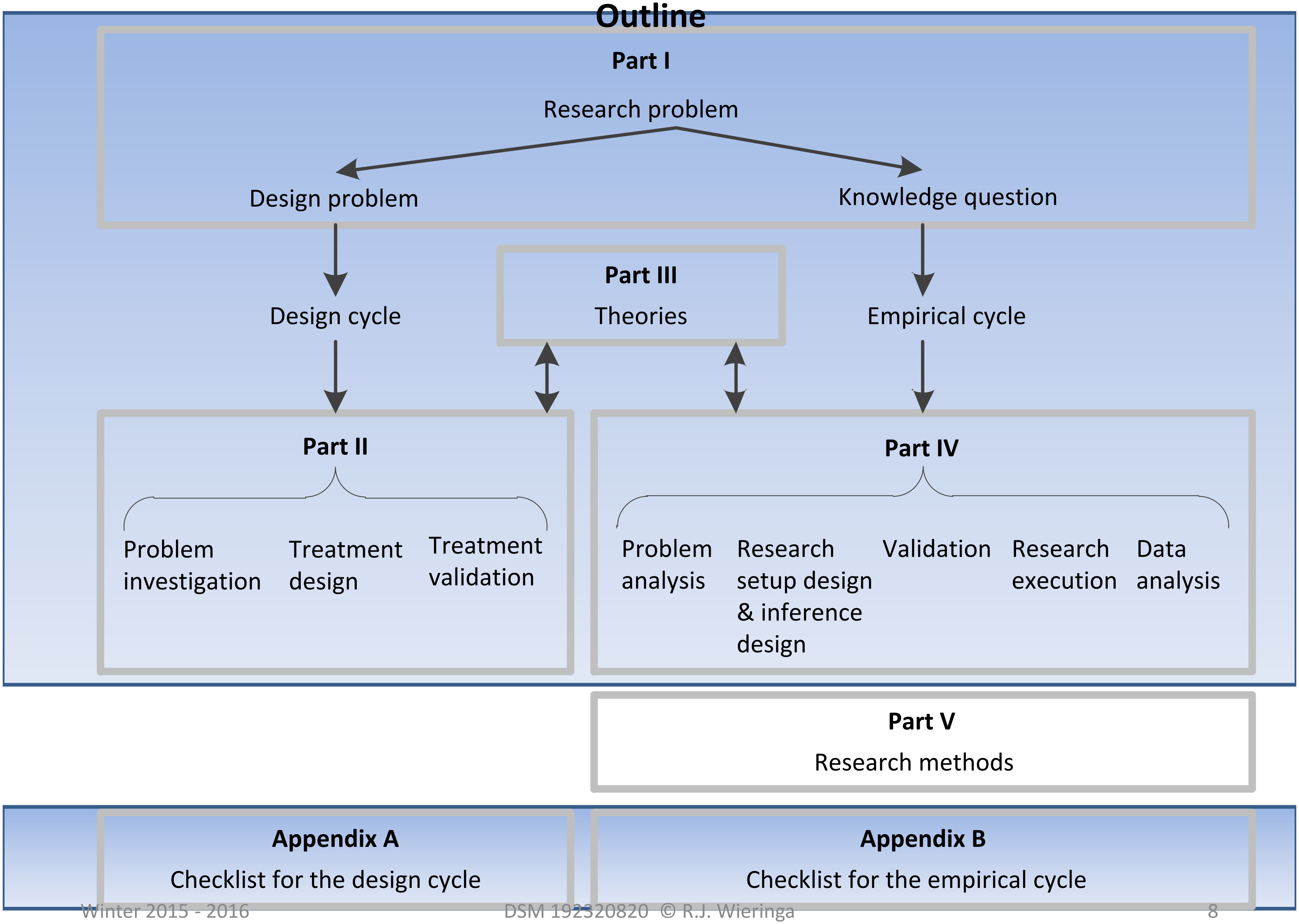
- (2) Knowledge questions
  - *Describe, explain, predict*
  - Questions, research design, research execution, data, analysis
  - **Empirical research cycle**
  - Truth is the goal
  - Utility is a side-effect

Focus on justification

- This is not a creativity course
    - Not about how to be original

- The course is about how to **justify** and **report** your research results
    - Why would anyone use your design? There are many other designs.
    - Why would anyone believe your answers? Opinions are cheap.
- This also helps you to organize the project itself.

Outline



Part I

Research problem

Design problem

Knowledge question

Design cycle

Part III

Theories

Empirical cycle

Part II

- Problem investigation
- Treatment design
- Treatment validation

Part IV

- Problem analysis
- Research setup design & inference design
- Validation
- Research execution
- Data analysis

Part V

Research methods

Appendix A

Checklist for the design cycle

Appendix B

Checklist for the empirical cycle

0.2 Organization of the course

Material

- Slides on BB
- Book http://link.springer.com/book/10.1007/978-3-662-43839-8
  - Free download within UT domain
- Questions and assignments on BB
  - Questions are possible exam questions!
  - Assignments to analyze recent Master's Theses are weekly homework, graded.

Weekly cycle

- Tuesday in the course:
  - Me: Discuss feedback on previous assignment.
  - One-slide treatment of new chapter(s).
  - Discuss questions about the chapter (see also Q&A questions).
  - Explain new assignment.
  - You, after the course: Start with it.
- Friday
  - You: Hand in the assignment before Friday 24:00 through Blackboard.
- Monday
  - You: Read chapters to be treated on Tuesday.
  - We: Grade the assignment and give feedback.

Weekly schedule

Calendar week	Day	Lesson	Chapters to read before the lecture	Assignments to do after the lecture
5	2-feb	1	0. Intro	
		1	1 What is design science	chapter 1
6	9-feb	2	2 Research goals and questions	chapter 2
		2	3 Design cycle	chapter 3
7	16-feb	3	4 stakeholders and goal analysis	chapter 4
		3	5 implementation evaluation	chapter 5
8	23-feb!!	4	6 Requirements specification	chapter 6
9	1-mrt			
10	8-mrt	5	7 Treatment validation	chapter 7
11	15-mrt	6	8 Conceptual frameworks	chapter 8
12	22-mrt	7	9 Scientific theories	chapter 9
13	29-mrt	8	10 Empirical cycle	chapter 10
		8	11 Empirical research design	chapter 11

Theses used for the assignments

- Ralph Broenink. *Finding relations between botnet C&Cs for forensic purposes*, May 2014. http://essay.utwente.nl/64998/.
- Sandra Drenthen. *Towards continuous delivery in system integration projects : introducing a strategy to achieve continuous delivery and test automation with FitNesse*, February 2014. http://essay.utwente.nl/64984/.
- Paulus Schoutsen. *Fraud detection within medicaid*, 2012. http://essay.utwente.nl/62854/.
- Pier van der Graaf. *EPR in the Dutch hospitals - a decade of changes: a study about EPR system's success factors in the Dutch hospitals*, 2012. http://essay.utwente.nl/61456/.
- Shirin Zarghami. *Middleware for internet of things*, November 2013. http://essay.utwente.nl/64431/.

Groups of 2

- **Register on blackboard**
  - “Group Enroll” button
  - Enroll in one of the groups which does not have 2 people enrolled yet
- Before **today 24:00**
  - If you are not enrolled in a group by that time, we will conclude that you will not participate in the course
  - Single-person groups will be merged by us into 2-person groups as far as possible

How to do the assignments

- First, each of you separately
- Then jointly, resolving differences

- There is no single solution, but there are good and bad solutions
    - The quality of a solution proposal is the quality of its
    - **justification**
    - The quality of an answer is the quality of its …….

- Write for the reader who
    - has forgotten all details of the thesis, and
    - has forgotten what you wrote last week.
- Above all, be clear and brief

Grading

- Average mark of weekly assignments is W
- Written examination; mark is E
- Your final mark is
  - If E < 5.5, then E
  - Otherwise, (E+W)/2

Questions?

1 What is design science?

Main points chapter 1
What is design science

- Design science is the **design** and **investigation** of **artifacts** in **context**
  - Research problems are **design problems** or **knowledge questions**
  - Artifacts **interact** with their context to deliver a **service**
- The **social context** of a design science project consists of stakeholders and their goals and budgets.
- The **knowledge context** consists of scientific knowledge, design specifications, useful facts, practical knowledge, common sense, etc.
- The design sciences are **middle-range sciences** aiming for partial generalizations about realistic conditions.
  - Need to scale up from idealized to practical conditions

2.1 The subject of design science

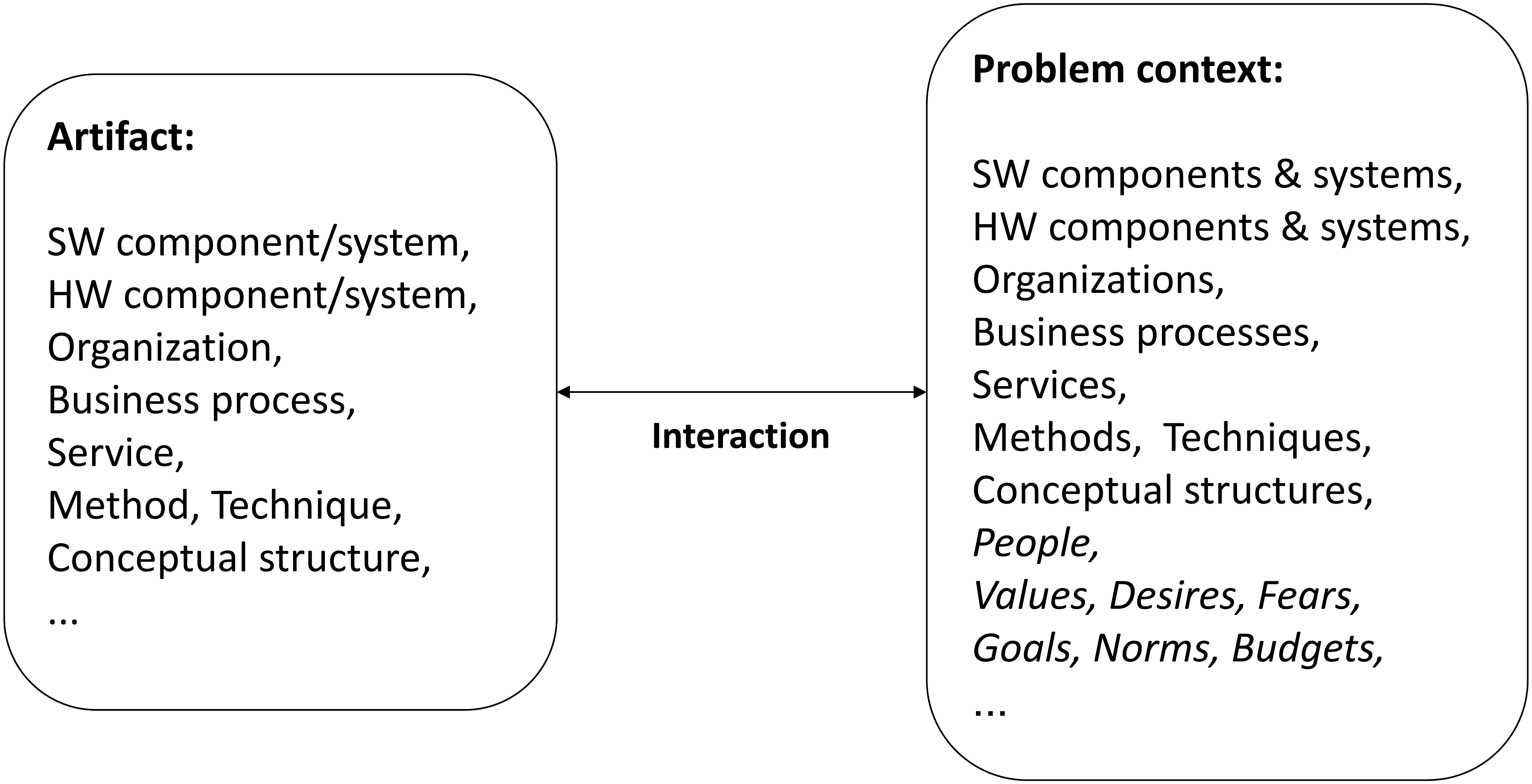
- Design science is the **design** and **investigation** of artifacts in context

Reality check

- http://essay.utwente.nl/view/programme/

- Design of conceptual / physical / software / social structures

Subject of design science



Artifact:

SW component/system,
HW component/system,
Organization,
Business process,
Service,
Method, Technique,
Conceptual structure,
...

Interaction

Problem context:

SW components & systems,
HW components & systems,
Organizations,
Business processes,
Services,
Methods, Techniques,
Conceptual structures,
People,
Values, Desires, Fears,
Goals, Norms, Budgets,
...

Something to be designed

Something to be influenced

What is designed and what is given

- The problem context is given to you
  - It is not designed by you

- The (renewed) artifact is (re)designed by you
  - It is not given to you
  - An older version of the artifact may be given to you

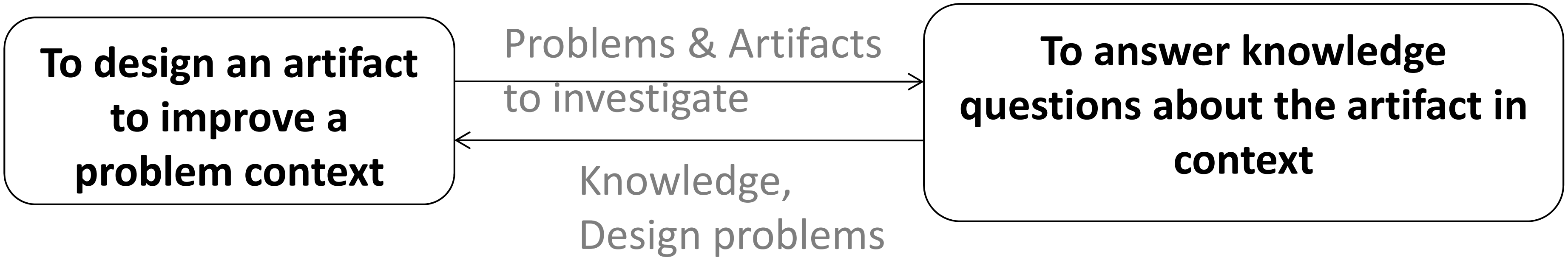
Interaction should provide a service for the context

- The artifact interacts with the problem context … in order to improve the context
- The interaction provides a **service** to the problem context

- Design science studies
  - behavior of artifacts in context
  - and its contribution to stakeholder goals

2.2 Research problems in design science

Research problems in design science



To design an artifact to improve a problem context

Problems & Artifacts to investigate

Knowledge, Design problems

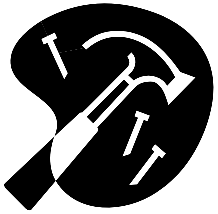
To answer knowledge questions about the artifact in context

Heuristics

- Design problems

  √ Call for a change of the world
  √ Solution is design
  √ Many solutions
  √ Evaluated by utility
  √ Many degrees of utility

  √ What is useful depends on stakeholder goals

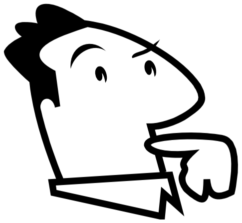


Doing

- Knowledge questions

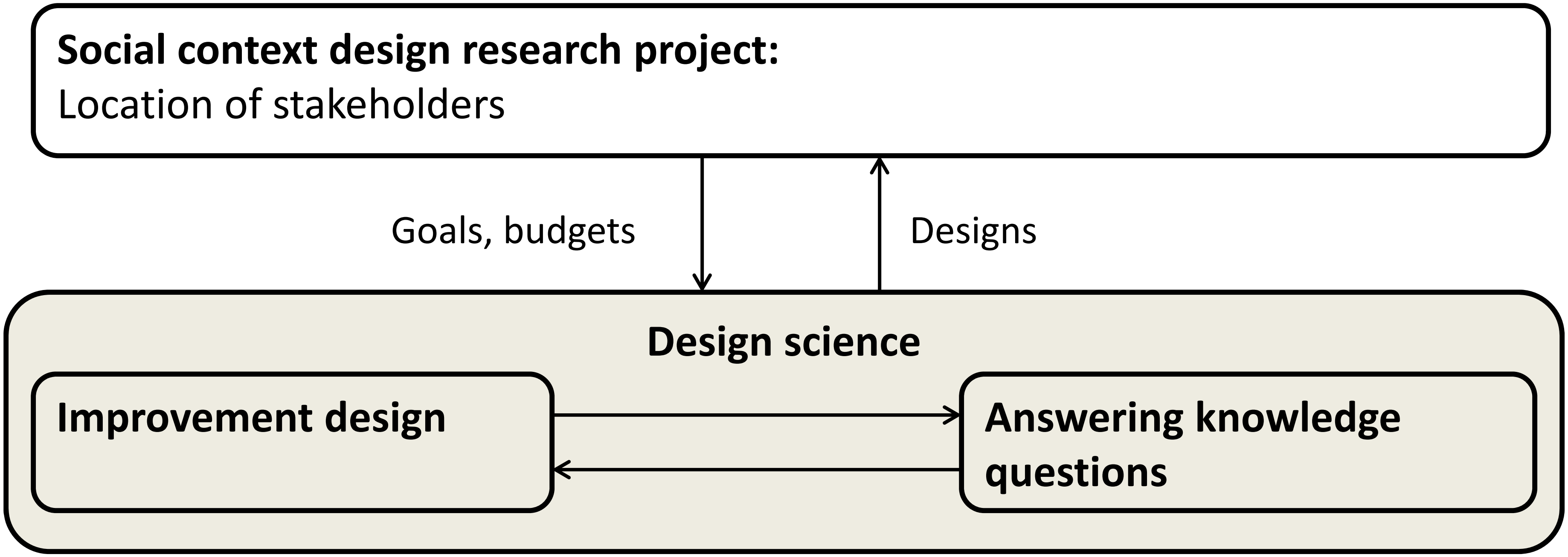
  √ Ask for knowledge about the world
  √ Answer is a proposition
  √ One answer
  √ Evaluated by truth
  √ Many degrees of certainty about the answer
  √ What is considered “true” does not depend on stakeholder goals
  http://www.factcheck.org/

Thinking



2.3 The social context of a design science project

The social context of design research



Social context design research project:
Location of stakeholders

Goals, budgets

Designs

Design science

Improvement design

Answering knowledge questions

"Design a DoA estimation system to be used in cars":

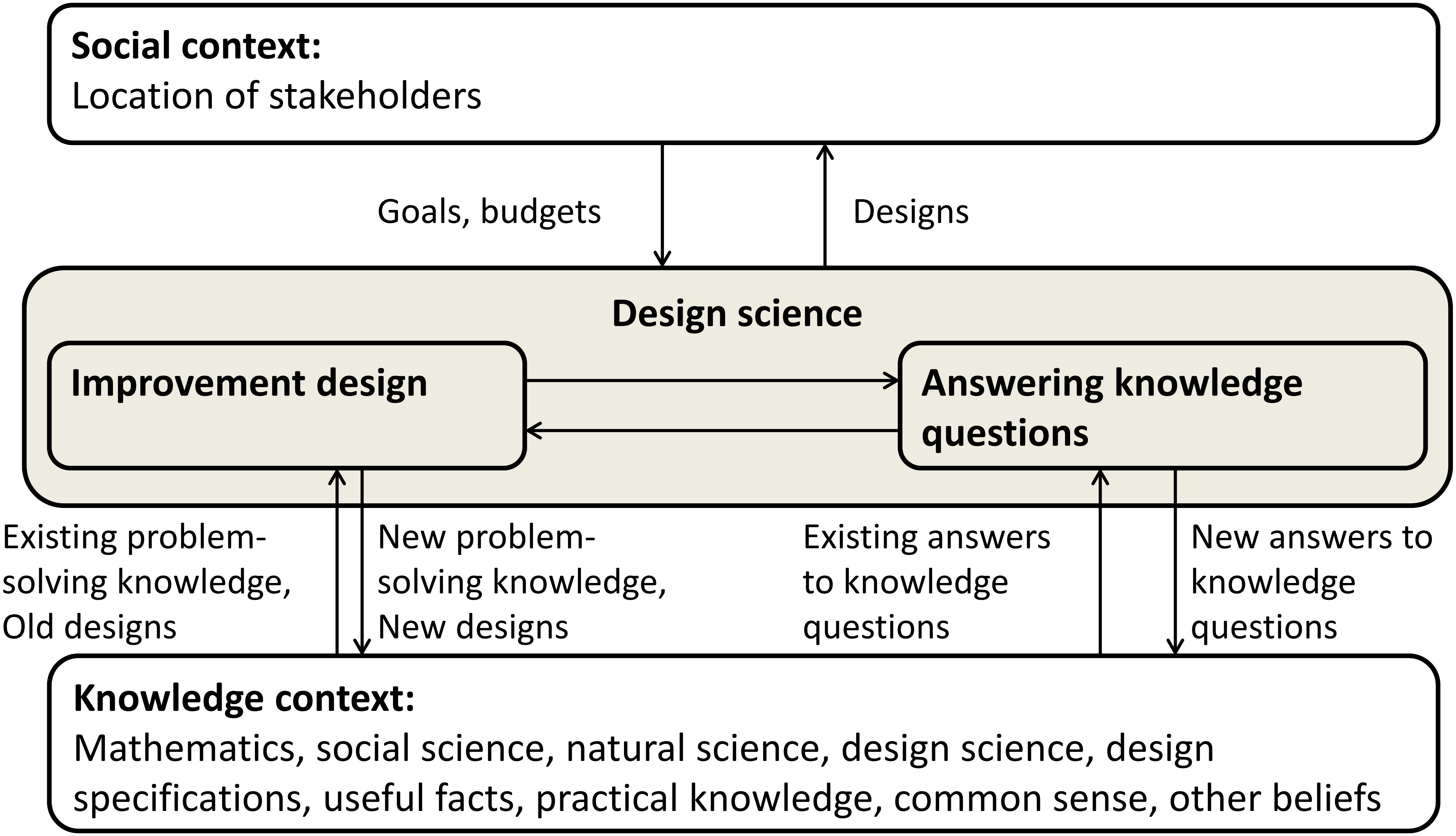
> *Stakeholders: Researchers, NXP (sponsor), component suppliers, car manufacturers, garages, car passengers*

"Design an assurance method for cloud service provider data compliance".

> *Stakeholders: KPMG (sponsor), KPMG consultants (end-users), researchers, CSPs, CPS clients.*

2.4 The knowledge context of a design science project

The context of design research



Social context:
Location of stakeholders

Goals, budgets

Designs

Design science

Improvement design

Answering knowledge questions

Existing problem-solving knowledge,
Old designs

New problem-solving knowledge,
New designs

Existing answers to knowledge questions

New answers to knowledge questions

Knowledge context:
Mathematics, social science, natural science, design science, design specifications, useful facts, practical knowledge, common sense, other beliefs

Knowledge sources

- Scientific literature
  - Scientific, peer reviewed journals and conferences (math, natural science, social science, design sciences)
- Technical literature
  - Design specifications, manuals
- Professional literature
  - Non-peer reviewed professional magazines, trade press, marketing literature, white papers (useful facts and opinions, practical knowledge, common sense)
- Oral communication
  - Colleagues, supervisors, practitioners (useful facts and opinions, practical knowledge, common sense, other beliefs)

What about the Web?

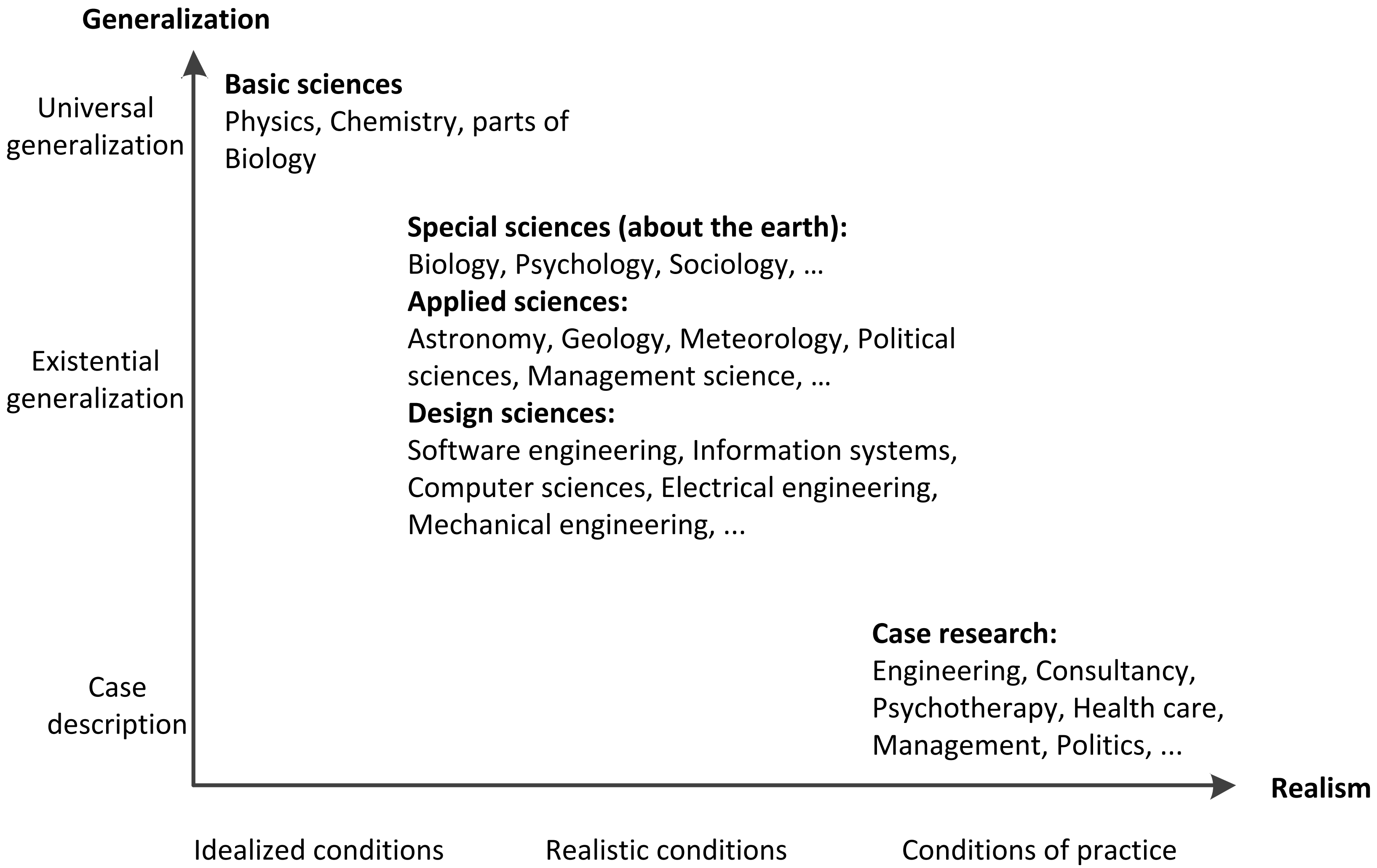
- The Web is a communication channel, not a source of information
- Sources are more diverse
  - Scientific literature
  - Technical literature
  - Professional literature
  - On-line databases
  - Social networks
- Did the information survive
  - Empirical tests?
  - Critical judgment of peers?

Your research aims at theories

- Knowing the relevant properties of an artifact in context is not enough
  - Theories are general

- If the artifact prototype that you built disappears, what is the knowledge remains?
  - Tested, critiqued knowledge

Sciences of the middle range



Generalization

Universal generalization

Existential generalization

Case description

Basic sciences
Physics, Chemistry, parts of Biology

Special sciences (about the earth):
Biology, Psychology, Sociology, …

Applied sciences:
Astronomy, Geology, Meteorology, Political sciences, Management science, …

Design sciences:
Software engineering, Information systems, Computer sciences, Electrical engineering, Mechanical engineering, ...

Case research:
Engineering, Consultancy, Psychotherapy, Health care, Management, Politics, ...

Realism

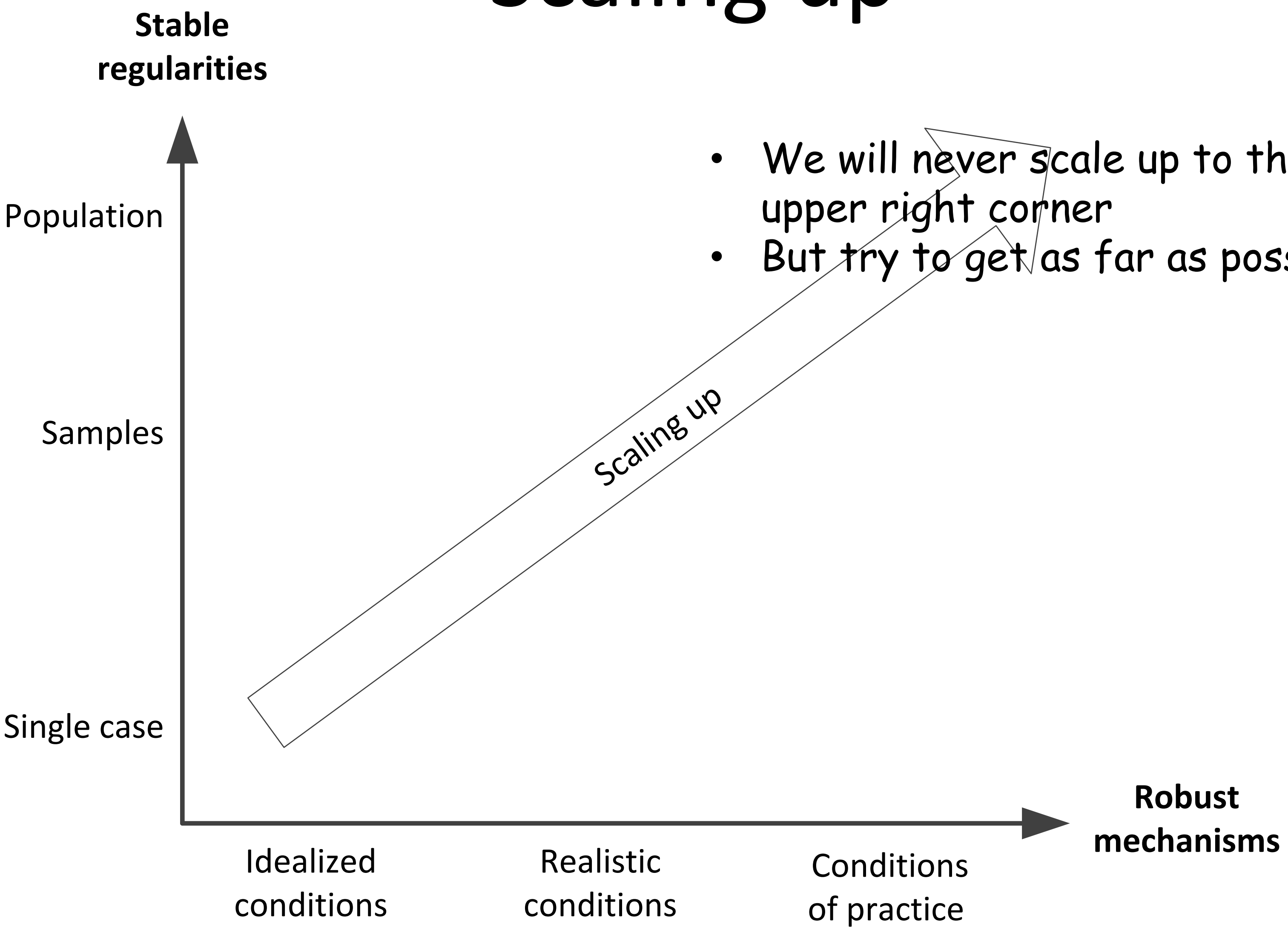
Idealized conditions

Realistic conditions

Conditions of practice

- Useful idealizations in software engineering and information systems
  - All clocks are synchronized and correct
  - Synchronicity of response and stimulus
  - Unlimited memory (Turing machines)
  - Message arrival guarantees
  - Rational users
  - Organizations with a clearly defined structure
  - …
- Conditions of practice
  - Incorrect input
  - Messages get lost
  - Timeouts are discovered too late
  - Clocks drift
  - Users do not behave according to expectations
  - …

Scaling up



- We will never scale up to the upper right corner
- But try to get as far as possible

Assignment chapter 1

- Ralph Broenink. *Finding relations between botnet C&Cs for forensic purposes*, May 2014.
- Paulus Schoutsen. *Fraud detection within medicaid*, 2012.
- Pier van der Graaf. *EPR in the Dutch hospitals*, 2012.
- Page 5 in Q&A

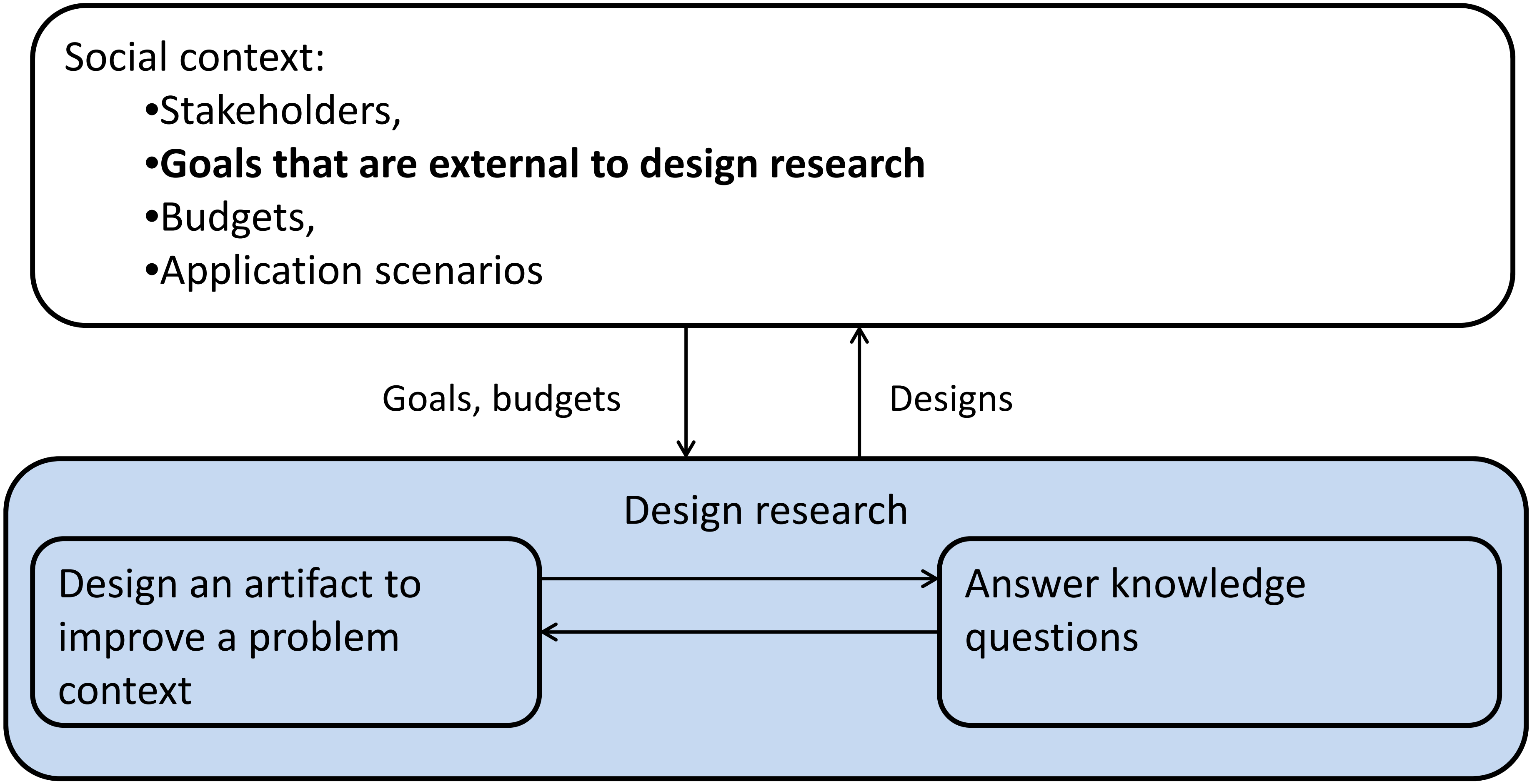
2. Research Goals and Research Questions

Main points chapter 2
Research goals & questions

- A design science projects has goals that range from designing an instrument (lowest level) to contribution to external stakeholder goals (highest level).
  - The highest-level research goal is to (re)design an artifact
  - This may be decomposed into design problems, prediction problems, and knowledge questions
- Knowledge questions may be analytical or empirical.
  - Empirical knowledge questions may be
    - descriptive or explanatory,
    - open or closed,
    - effect-related or requirement-related
- The answers to knowledge questions may be used to solve design and prediction problems

2.1 Research goals

External goals



Social context:

- Stakeholders,
- **Goals that are external to design research**
- Budgets,
- Application scenarios

Goals, budgets

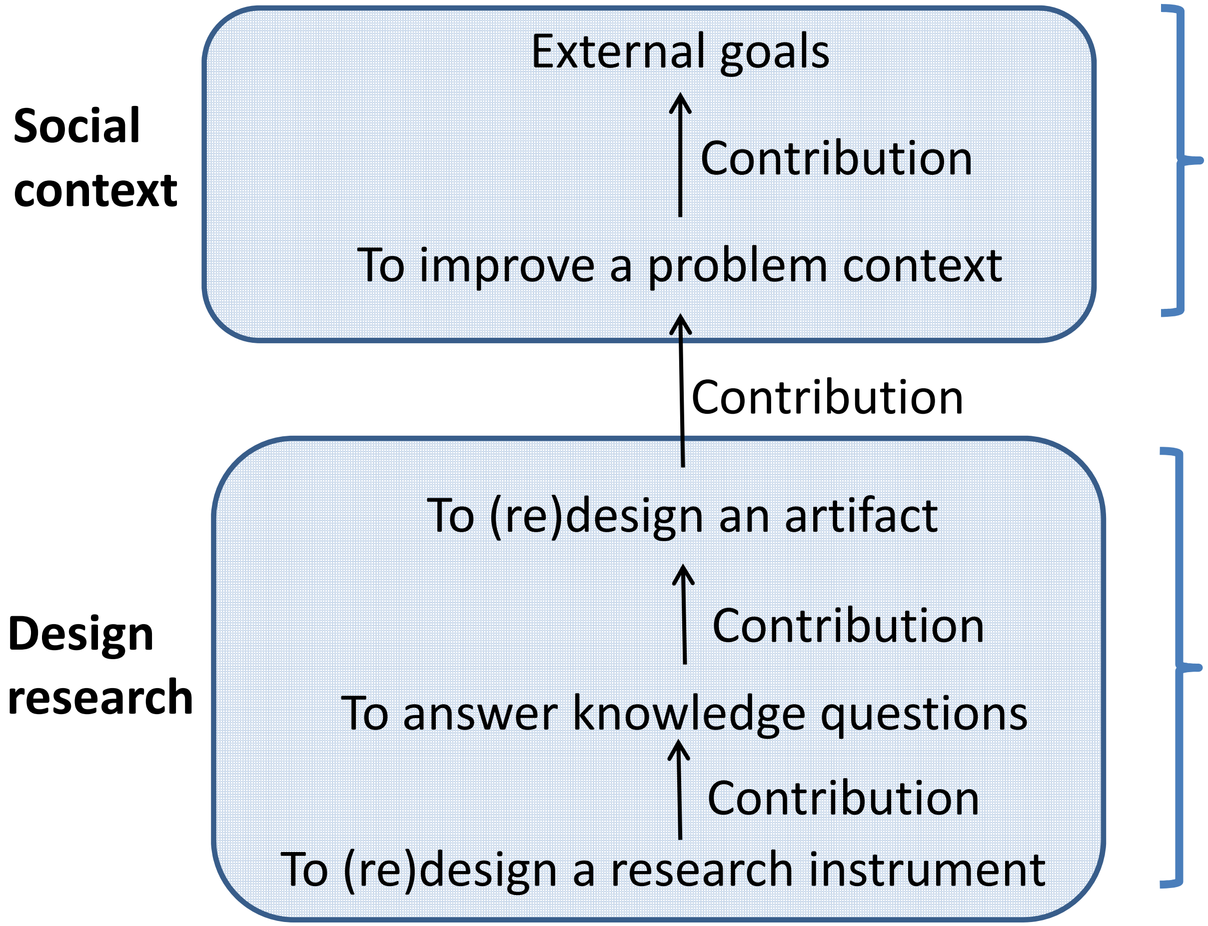
Designs

Design research

Design an artifact to improve a problem context

Answer knowledge questions

Goal structure



Motivation of the research goal: friends, family, the government, sponsors, investors, etc. are interested in these.

A design **research goal** is he desired outcome of a research project, to which the research budget is allocated. Colleagues are interested in these.

Examples

Ucare

- *External goals:*
  - *Reduce health care cost (government)*
  - *Reduce work pressure, increase quality of care (health personnel)*
  - *Increase quality of care, increasse independence (elderly)*
- *Design goals*
  - *Design a mobile home care system for use by elderly that provides*
    - *Medicine dispensing*
    - *Blood pressure monitoring*
    - *Agenda*
    - *Remote medical advice*

Two kinds of design research questions

- To achieve the design goal, we need to answer research questions.
  - Design problems
    - A.k.a. technical research questions
  - Knowledge questions
    - Analytical research questions: can be answered by analysis
    - Empirical research questions: must be answered by collecting data

2.2 Design problems

Template for design problems

- Improve <problem context>
- by <treating it with a (re)designed artifact>
- such that <artifact requirements>
- in order to <stakeholder goals>

- *Improve my body / mind health*
- *by taking a medicine*
- *such that relieves my headache*
- *in order for me to get back to work*

Template for design problems

- Improve <problem context>
- by <treating it with a (re)designed artifact>
- such that <artifact requirements>
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Problem context and stakeholder goals

Template for design problems

- Improve <problem context>
- by <treating it with a (re)designed artifact>
- such that <artifact requirements>
- in order to <stakeholder goals>

- *Improve my body / mind health*
- ***by taking a medicine***
- ***such that relieves my headache***
- *in order for me to get back to work*

Artifact and its desired interactions

Template for design problems

- Improve <problem context>
- by <treating it with a (re)designed artifact>
- such that <artifact requirements>
- in order to <stakeholder goals>

- *Improve my body / mind health*
- *by taking a medicine*
- *such that relieves my headache*
- *in order for me to get back to work*

- *Improve home care*
- *By a mobile support device*
- *That provides some services …*
- *So that cost are reduced etc.*

2.3 Knowledge questions

Kinds of empirical knowledge questions

- Empirical knowledge questions may be
  - descriptive or explanatory,
  - open or closed,
  - effect-related or requirement-related

Knowledge questions

- **Descriptive questions:**
  - What happened?
  - When?
  - Where?
  - What components were involved?
  - Who was involved?
  - etc.

Journalistic questions,
Provide facts

- **Explanatory questions:**
  - Why?
    1. What has **caused** the phenomena?
    2. Which **mechanisms** produced the phenomena?
    3. For what **reasons** did people do this?

Example

- *Descriptive question: What is the performance of the Ucare system?*
  - *Accuracy of output*
  - *Reliability of communication infrastructure*
  - *Usability of interfaces*
  - *Etc. etc.*
- *Explanatory question: Why does Ucare have this performance?*
  1. ***Cause:** data entrance at 03:00 causes the datya to be lost*
  2. ***Mechanism:** because the hospital database server is down for maintainance at night and there is no fallback retention mechanism*
  3. ***Reasons:** Users feel free to enter data any time they are awake, and they are awake at 03:00.*

Prediction problems

- There are no predictive knowledge **questions**
  - We cannot know the future
  - Descriptive and explanatory **questions** are about the present and the past
- But there are prediction **problems**
  - *How will the program behave when given this input?*
  - *How would users behave when the program is changed?*
- To solve a prediction problem, we need a theory that tells us what usually happens.

Second classification of knowledge questions

- **Open questions (exploration):**
  - No hypothesis about the answers.
    - *What is the execution time?*
- **Closed questions (testing):**
  - Specific, testable hypotheses as possible answers.
    - *Is execution time is less than 1 second?*
      - *Hypothesis: the execution time is less than 1 second.*

Third classification: Design research questions

- **Effect question:** Context X Artifact → Which Effects?
  - **Trade-off question:** Context X ***Alternative artifact*** → Effects?
  - **Sensitivity question:** ***Other context*** X artifact → Effects?
- **Requirements satisfaction question:** Do these Effects satisfy requirements sufficiently?

Example

- *Open descriptive effect questions: What is the performance of the Ucare system?*
  - *Accuracy of output*
  - *Reliability of communication infrastructure*
  - *Usability of interfaces*
  - *Etc. etc.*
- *Open descriptive trade-off questions*
  - *What happens to the performance iof we change the design?*
- *Open descriptive sensitivity questions:*
  - *What happens if it is used by other elderly, in other homes?*
- *Open explanatory questions:*
  - *Why does Ucare have this performance?*
- *Open descriptive requirements satisfaction questions:*
  - *Does this satisfy our requirements?*

Assignment chapter 2

- Broenink (2014) - *Finding Relations Between Botnet C&Cs for Forensic Purposes*
- Drenthen (2014) - *Towards continuous delivery in system integration projects*
- Van der Graaf (2012) - *EPR in Dutch hospitals-a decade of changes*
- Page 8 in Q&A

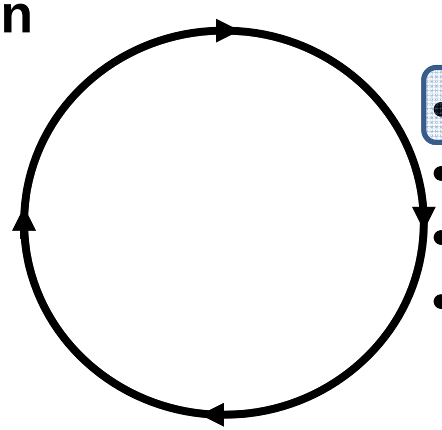
4. Stakeholder and Goal Analysis

Main points chapter 4
Stakeholder and goal analysis

- A **stakeholder** of a problem is a biological or legal person affected by treating a problem
  - Positively or negatively affected
  - There are checklists of possible stakeholders
- A **goal** of a stakeholder is a *desire* to the realization of which the stakeholder has *committed* resources (time, money)
  - Desires are many, goals are few
- Desires may **conflict** with each other
  - Therefore, goals may conflict too.
  - Logical, physical, technical, economic, legal, moral conflict

Engineering cycle

! = **Action**
? = **Knowledge question**



Design implementation

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Conceptual problem framework?
- Phenomena? Causes, mechanisms, reasons?
- Effects? Positive/negative goal contribution?

Design validation

- Context & Artifact → Effects?
- Effects satisfy Requirements?
- Trade-offs for different artifacts?
- Sensitivity for different Contexts?

Treatment design

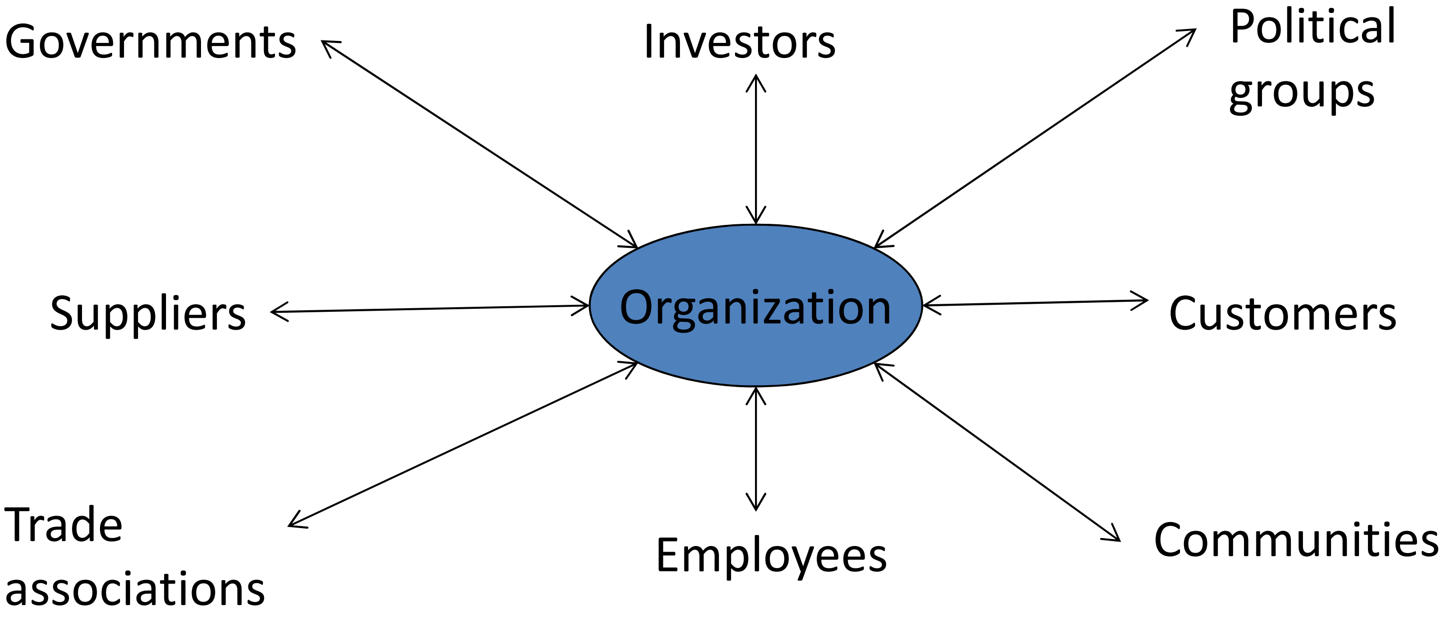
- Specify requirements!
- Requirements contribute to goals?
- Available treatments?
- Design new ones!

4.1 Stakeholders

Stakeholders

- A **stakeholder** of a problem is a biological or legal person affected by treating a problem.
  - *People, organizations, job roles, contractual roles, etc.*
- Typical stakeholders of a **design research project**
  - *Researchers, sponsors, developers, users, etc.*
  - They have an interest in the outcome.
- Typical stakeholders of a **development project**
  - *Designers, programmers, testers, users etc.*
- Typical stakeholders of a **software product**
  - See next slides

P. Clements, L. Bass. “Using business goals to inform software architecture.” *18th IEEE International Requirements Engineering Conference.* Pages 69-78. IEEE Computer Science Press. 2010.



Governments

Investors

Political groups

Suppliers

Organization

Customers

Trade associations

Employees

Communities

- The organization may be a company, government organization, department, project, etc.

Checklist by role (Ian Alexander http://www.scenarioplus.org.uk/papers/papers.htm > A taxonomy of stakeholders)

System under Development

- Normal operator (end user)
- Operational support
- Maintenance operator

Immediate context

- Functional beneficiary (client)
- Roles responsible for interfacing systems

Wider context

- Political beneficiary (who gains status)
- Financial beneficiary
- Negative stakeholder (who is/perceives to be hurt by the product)
- Threat agent (who wants to hurt the product)
- Regulator

Involved in development

- Champion/Sponsor
- Developer
- Consultant
- Purchaser (customer)
- Suppliers of components

None of these lists is complete

Examples of stakeholders

- *PISA: Design a system to help individuals to maintain their privacy on the internet at a desired level*
  - *Free lancer*
  - *Teleworker*
  - *Home banker*
  - *Concerned parent*
- *Ucare: Design a system that provides health care support for elderly people at home*
  - *Medicine taking*
  - *Blood pressure monitoring*
  - *Agenda*
  - *Remote advice*
- We omit researcher goals henceforth

4.2 Desires

Stakeholder awareness and commitment

Not aware:
Some possibility that stakeholders are not aware of

- *Possibility to receive satellite TV in car*
- *Possibility to reduce taxiing time*

An event pushes the possibility into awareness

Aware, not committed:
Not interested enough to commit resources (money, time)

Indifferences, Desires, Fears

- *We could upgrade car DVD player to TV*
- *We could optimize taxi routes dynamically*

Stakeholder makes resources (time, money) available

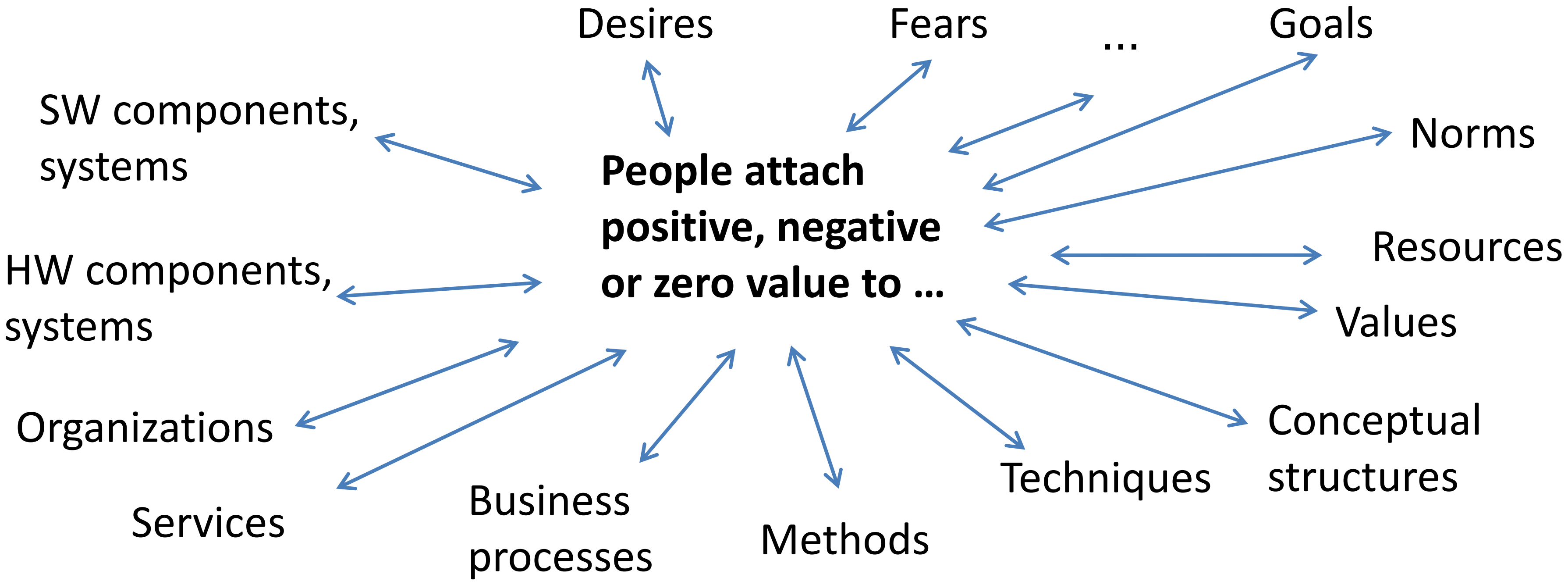
Aware & Committed:
Resources committed to act for a goal

Goals

- *Invest in car satellite TV*
- *Develop a prototype multi-agent route planning system*

- A **goal** of a stakeholder is a desire to the realization of which the stakeholder has comitted resources (time, money)
  - People want a lot but they have only a few goals
  - Some goals are imposed

Anything can be the object of desire, fear or indifference



People attach positive, negative or zero value to …

Desires

Fears

...

Goals

Norms

Resources

Values

Conceptual structures

Techniques

Methods

Business processes

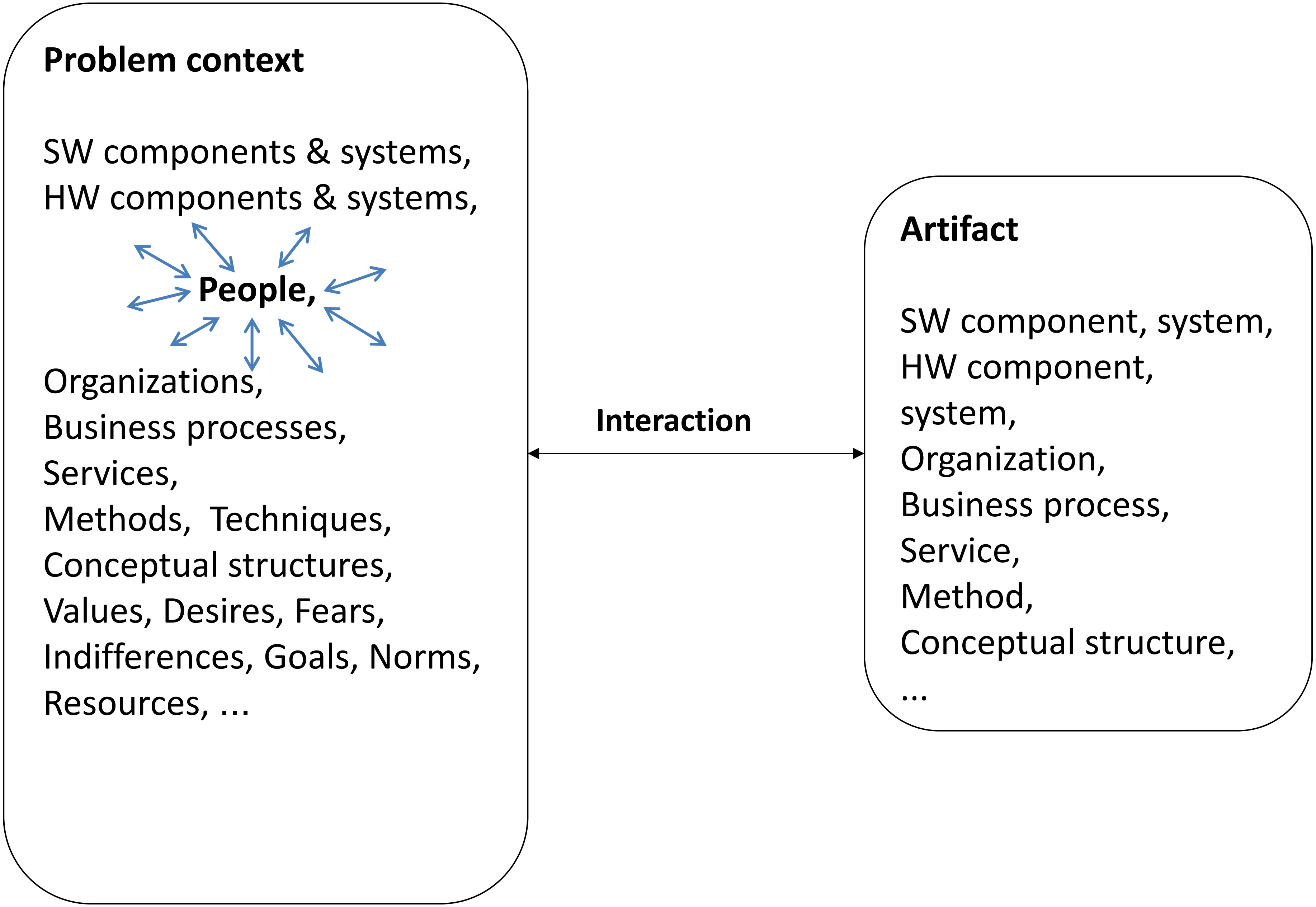
Services

Organizations

HW components, systems

SW components, systems

- Desires, fears and indifference are mental states:
  - They can be **directed upon** anything, whether real or imaginary
  - Every mental state is **about** something
  - They can even be about desire, fear or indifference



Problem context

SW components & systems,
HW components & systems,
People,
Organizations,
Business processes,
Services,
Methods, Techniques,
Conceptual structures,
Values, Desires, Fears,
Indifferences, Goals, Norms,
Resources, ...

Interaction

Artifact

SW component, system,
HW component,
system,
Organization,
Business process,
Service,
Method,
Conceptual structure,
...

Examples of problem contexts

- *Ucare: Design a system that provides health care support for elderly people at home.*
  - *Context: Patient's home*
    - *Patient and their physical and technical context, budget, desires, norms and values*
    - *Friends and their budget, desires, norms and values*
    - *Family and their budget, desires, norms and values*
    - *Home care nurses and their budget, desires, norms and values*
    - *Remote medical personnel and their budget, desires, norms and values*
    - *The law*
    - *Ethical constraints*

4.3 Desires and conflicts

The multitude of desires

- Any one stakeholder may have infinitely many potential desires, fears and indifferences
- Many desires of one or more stakeholders may conflict

Conflicting desires

- **Logical conflict*:***
  - Analysis of the descriptions of the desires shows that both descriptions have opposite meaning; they are logically inconsistent.
  - *Spend your money and keep it*
- **Physical conflict:**
  - Realization of one desire makes realization of the other physically impossible.
  - *Eat more and stay the same weight*
  - *Add TV to a car and reduce weight without changing anything else*
  - Stakeholder lives in a phantasy world

- **Technical conflict:**
  - There is currently no technology to realize both desires in the same artifact.
  - *Secure and user-friendly system*
  - New technology may remove the conflict
- **Economic conflict:**
  - Desires exceed the budget
- **Legal conflict:**
  - Desires contradict the law
- **Moral conflict:**
  - Desires contradict moral norms

Examples of conflicting desires

- *Ucare: Design a system that provides health care support for elderly people at home*
  - *Technical conflict: Artifact should be simple to use, but is fragile & advanced technology.*
  - *Economic conflict: Artifact should be cheap, but is expensive*
  - *Value conflict: patient likes Skyping more than the advice functions*

- Conflicts give us relevant design goals.

Assignment chapter 4

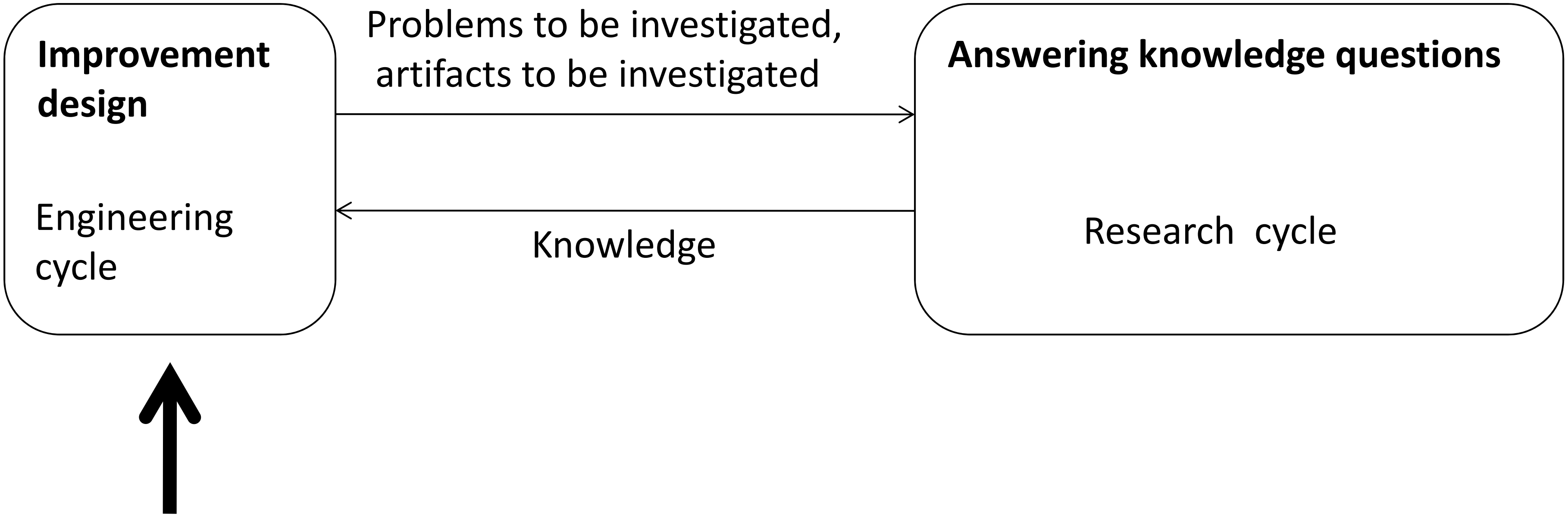
- Broenink (2014) - *Finding Relations Between Botnet C&Cs for Forensic Purposes*
- Drenthen (2014) - *Towards continuous delivery in system integration projects*
- Page 14 in Q&A

3 The design cycle

Main points chapter 3
The design cycle

- The engineering cycle is a rational decision cycle:
  - Problem/evaluation: Look where you are and what you want to do;
  - Design possible treatments;
  - Validate treatments without executing them;
  - Choose one and do it;
  - Evaluation/problem: Look where you are and what you want to do.
- The design cycle is the preparation for action:
  - Problem-design-validation.
- The cycles can be organized in many different ways.
  - All of them must allow you to justify your choices afterwards.
  - The engineering cycle allows you to justify your actions (validation) and to learn from their effects (evaluation)

Activities in design science



Improvement design

Engineering cycle

Problems to be investigated, artifacts to be investigated

Knowledge

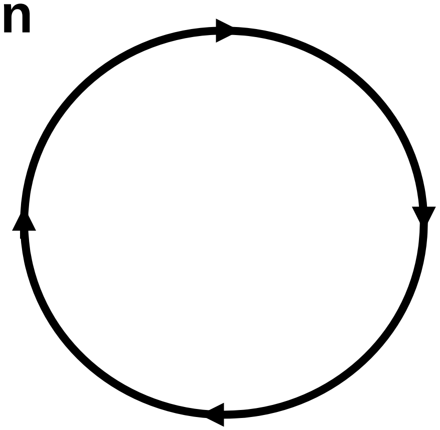
Answering knowledge questions

Research cycle

3.1 The design and engineering cycles

Engineering cycle

! = **Action**
? = **Knowledge question**



Design implementation

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Conceptual problem framework?
- Phenomena? Causes, mechanisms, reasons?
- Effects? Positive/negative goal contribution?

Treatment design

- Specify requirements!
- Requirements contribute to goals?
- Available treatments?
- Design new ones!

Treatment validation

- Context & Artifact → Effects?
- Effects satisfy Requirements?
- Trade-offs for different artifacts?
- Sensitivity for different Contexts?

Treatment

- We avoid the word “solution”.
  - – Every solution is imperfect
  - – … and introduces new problems

Specification and design

- Treatments are designed, and the design is specified

- **Designing** is deciding what to do
- **Specifying** is documenting that decision

- Contrast with the terminology in software engineering
  - Word games with ``what'' and ``how''.

What is implementation?

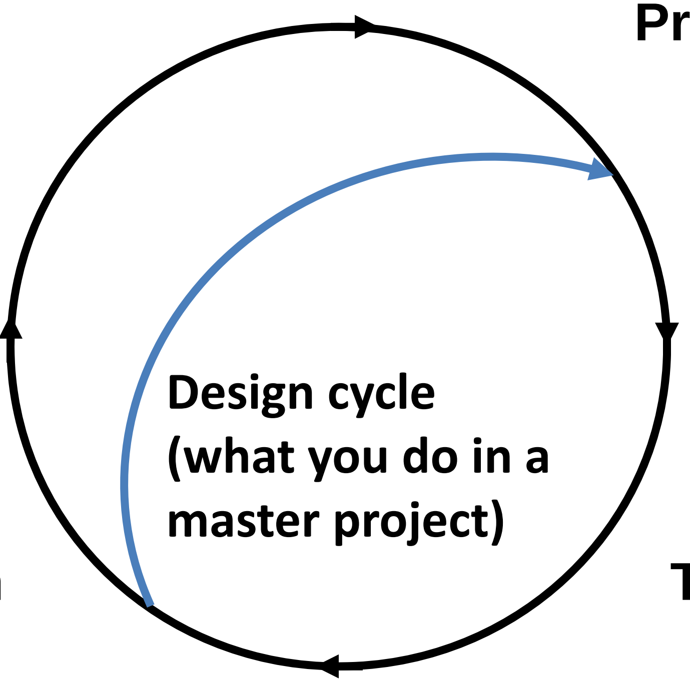
- Depends on who you talk to
  - *For a software engineer, this is writing and debugging a program until it works.*
  - *For a mechanical engineer, this is assembling the physical machine until it works*
  - *For the manager, this is introducing the machine in the organization until it works*
  - *For a marketeer, this is selling the system*

Implementation

- **Implementation** = introducing an artifact in the problem context
  - What this means depends on what your problem was
  - *For a software engineer: To construct software*
  - *For a mechanical engineer: To construct physical machine*
  - *For the manager: To change an organization*
  - *For a marketeer: To sell a product*

- In this course, our problems are real-world problems
  - Implementation = transfer to the problem context
  - = technology transfer to the real world

Design cycle



Design implementation

Implementation evaluation = Problem investigation

Treatment design

Treatment validation

Design cycle (what you do in a master project)

- Design research projects iterate one or more times through the design cycle.

Validation versus evaluation

- To **validate** a design for stakeholders is to justify that it would contribute to their goals **before** transfer to practice
  - Predicted effects?
  - Satisfaction of requirements?
  - (Requirements contribute to goals?)

- To **evaluate** an implementation is to investigate whether an implementation has contributed to to stakeholder goals **after** transfer to practice
  - Stakeholders, goals?
  - Effects?
  - Contribution?

What is the difference?

- **Implementation valuation** research studies real-world implementations with respect to actual stakeholder goals
  - Real-world research
- **Treatment validation** research uses a validation model to predict effects
  - Simulation

What kind of project do you have?

- Some projects do **implementation evaluation**
  - *E.g. investigate how UML is used in practice*
  - *Investigate traffic flow on internet*
  - *Investigate why our project effort estimations are always so wrong*
- Many projects **design and validate treatments**
  - *E.g. improve malware detection methods to get higher accuracy*
  - *Explore the use of social networks to communicate with our customers*

This determines the kind of research questions that you can ask

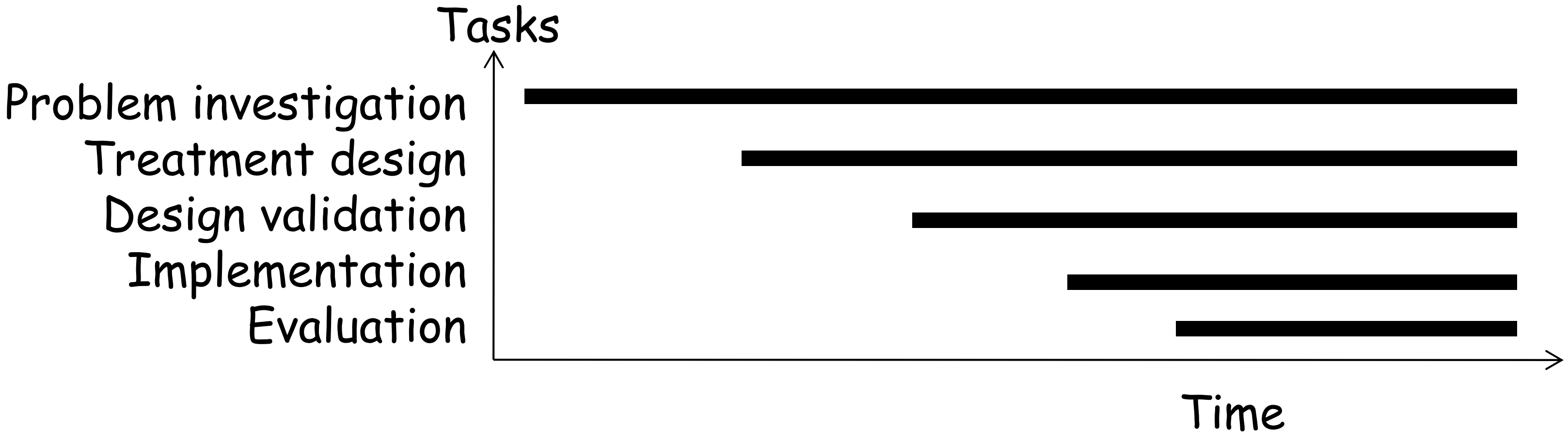
3.2 Design and engineering processes

- The design and engineering cycles are **rational reconstructions** of design and engineering
  - Rational reconstruction of mathematical proofs
  - Of empirical research
  - Of administrative processes

- The design and engineering **processes** execute tasks in different orders
  - Resources (time, money, people) must be managed
  - Deliverables nmust be scheduled, deadlines must be met

Concurrent engineering

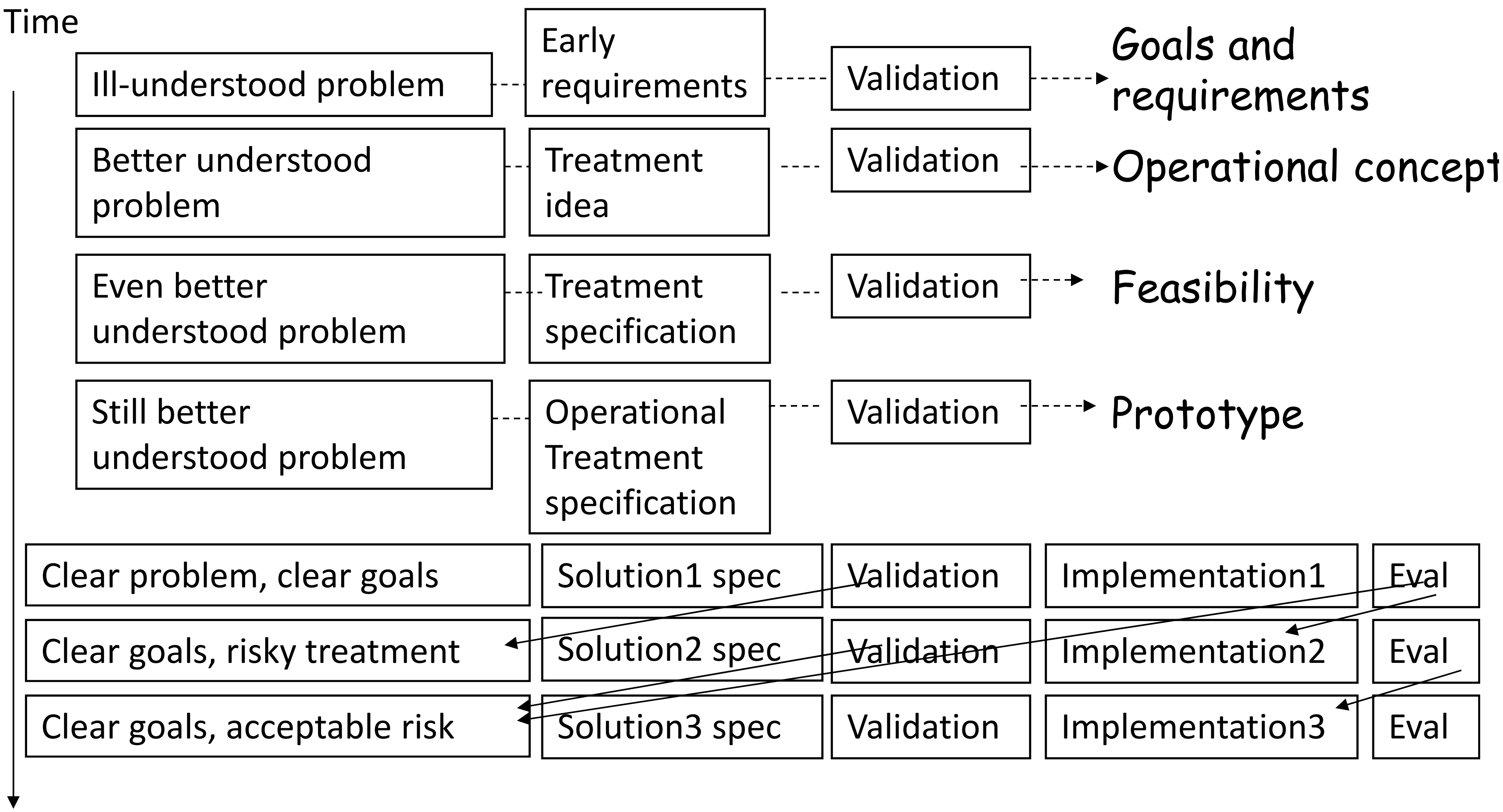
- Development may be organized concurrently with successive versions of the artifact



Systems engineering

- Cycles of systems engineering
  - High level goals, high level requirements
  - Iterative refinement until
  - Low-level approved interfaces, low-level implemented specs.

- Shown on next slide



Time

Ill-understood problem | Early requirements | Validation → Goals and requirements

Better understood problem | Treatment idea | Validation → Operational concept

Even better understood problem | Treatment specification | Validation → Feasibility

Still better understood problem | Operational Treatment specification | Validation → Prototype

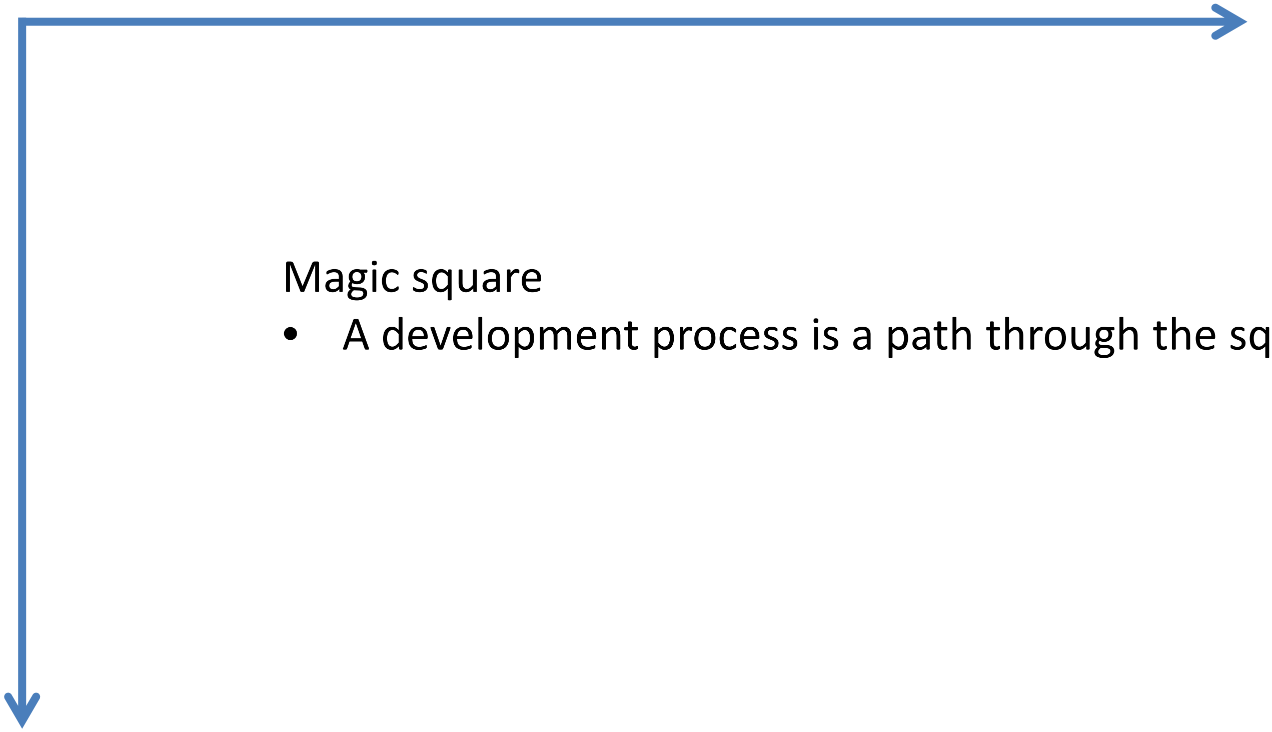
Clear problem, clear goals | Solution1 spec | Validation | Implementation1 | Eval

Clear goals, risky treatment | Solution2 spec | Validation | Implementation2 | Eval

Clear goals, acceptable risk | Solution3 spec | Validation | Implementation3 | Eval

- Iteratively reduce uncertainty about the problem
- Once the goals are clear enough, reduce risk of choosing the wrong treatment

Two kinds of design decisions



Adding information about a component

Refinement

Adding
components

Architectural
decomposition

Magic square

- A development process is a path through the square

Engineering management

- Management is the art of achieving results by the work of others.
  - Acquiring resources
  - Organizing them
  - Planning work
  - Managing risks
  - Motivating people
  - Evaluating outcomes

Systems engineering is a particular way to plan work & manage risks

Assignment chapter 3

- Broenink (2014) - *Finding Relations Between Botnet C&Cs for Forensic Purposes*
- Drenthen (2014) - *Towards continuous delivery in system integration projects*
- Schoutsen (2012) - *Fraud detection within Medicaid*
- Page 10 in Q&A

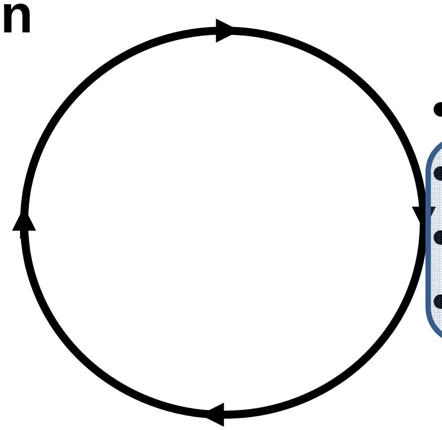
5 Implementation Evaluation and Problem Investigation

Main points chapter 5 Implementation evaluation & problem investigation

- Implementation evaluation and problem investigation have different research goals but the same research questions.
  - Who are the stakeholders? What are their goals?
  - What conceptual framework shall we use to describe the phenomena?
  - What are the phenomena? Their causes, mechanisms, reasons?
  - What if we do nothing? How good/bad wrt goals?
- Useful research methods are
  - surveys,
  - observational case studies,
  - single-case mechanism experiments and
  - statistical difference-making experiments

Engineering cycle

! = **Action**
? = **Knowledge question**



Design implementation

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Conceptual problem framework?
- Phenomena? Causes, mechanisms, reasons?
- Effects? Positive/negative goal contribution?

Design validation

- Context & Artifact → Effects?
- Effects satisfy Requirements?
- Trade-offs for different artifacts?
- Sensitivity for different Contexts?

Treatment design

- Specify requirements!
- Requirements contribute to goals?
- Available treatments?
- Design new ones!

5.1 Research goals

Two top-level goals

- **Implementation evaluation** is the investigation of the effects of a treatment implementation *after* the improvement has been implemented
- **Problem investigation** is the investigation of the problem context *before* an improvement is undertaken
- There is always a current implementation of *something*!
  - So the research questions are the same, only the goals are different.

Examples

- Implementation evaluation
  - *Investigate the use of the UML in companies in Brazil. Our goal is to find out the extent of usage.*
  - *Investigate the sources of phishing messages received by our organization. Our goal is to find out how bad it is.*

- Problem investigation
  - *Investigate the causes why our effort estimations are usually wrong. Our goal is to find improvement opportunities.*
  - *Investigate coordination problems in global software engineering projects. Our goal is to reduce these problems.*

Research questions for implementation evaluation & problem investigation

- Effect questions
  - Descriptive: What effects does the implemented artifact have? Explanatory: Why do these effects arise? (causes, mechanisms, reasons)
- Goal contribution questions
  - Evaluative: Do they contribute to/detract from stakeholder goals? To which extent?
  - Explanatory: why does this happen? (causes, mechanisms, reasons)

5.2 Theories

Scientific theories

- A scientific theory is a belief about patterns in phenomena that has
  - been validated against experience
  - survived criticism by critical peers

- Examples
  - *Theory of classical mechanics*
  - *Theory of evolution*
  - *Theory of cognitive dissionance*
- Non-examples
  - *Theory that the gods were astronauts*
  - *Conspiracy theories about who killed president Kennedy*
  - *The belief that my thoughts are monitored by aliens*

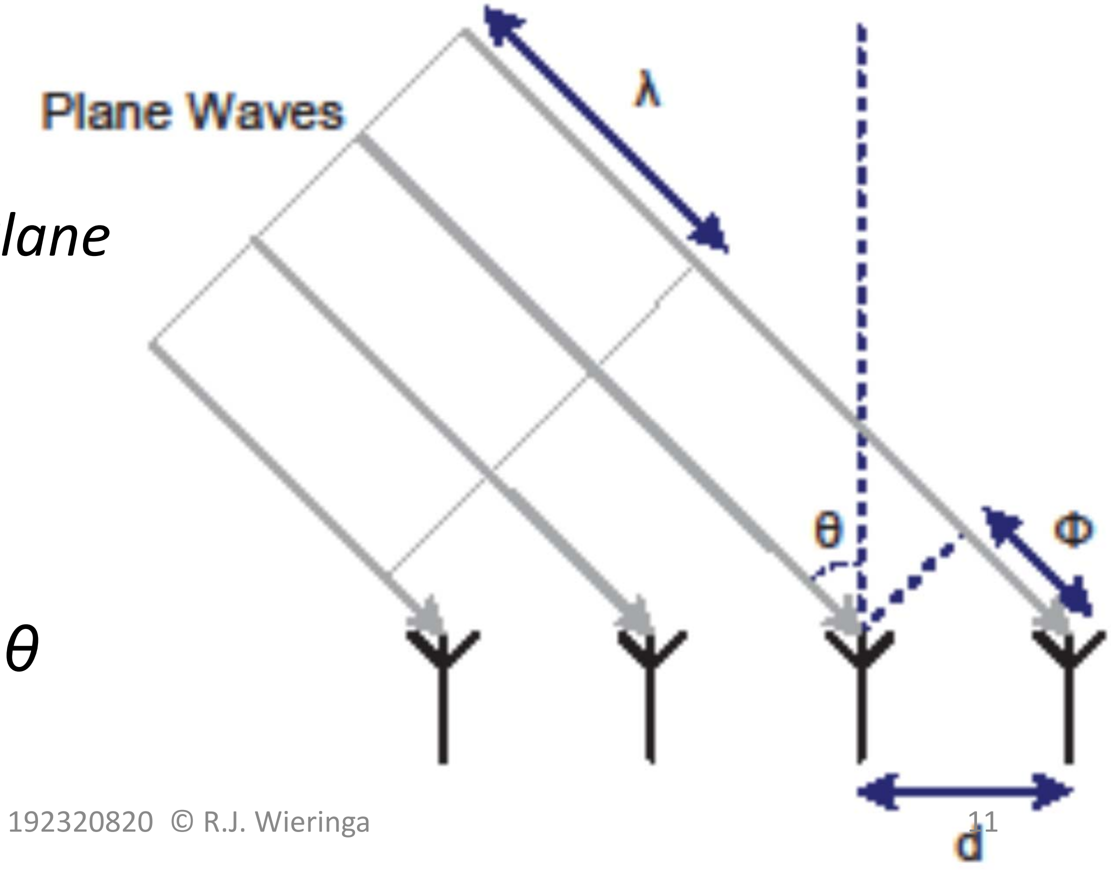
Problem theories

- Scientific theory of a problem
  - beliefs about problem patterns that have been validated against experience and survived critical analysis by peers

- *Ucare project: Design a system that provides health care support for elderly people at home.*
- *Problem theory:*
  - *People stay home till a higher age than previously*
  - *Travelling to health care centers is unpleasant*
  - *Health care personnel is expensive and is overburdened*
  - *Health care budgets grow at unsustainable rate*
  - *…*

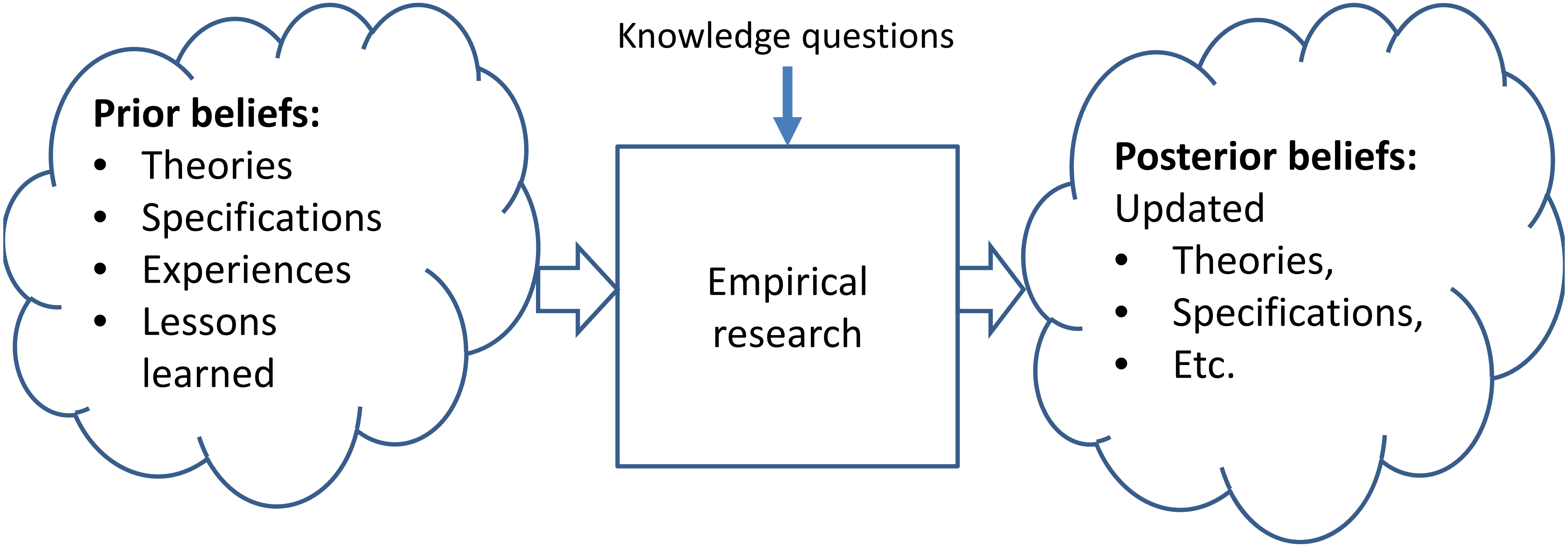
Satellite TV reception system for a car, contains an antenna array. Problem to be solved by a software system: recognize direction of arrival of plane waves.

Problem theory:



- *Definitions of concepts: Plane waves, wave length, bandwidth, etc.*
- *Generalization about the problem: φ= 2π (d/λ) sin θ*

5.3 Research Methods



Prior beliefs:

- Theories
- Specifications
- Experiences
- Lessons learned

Knowledge questions

Empirical research

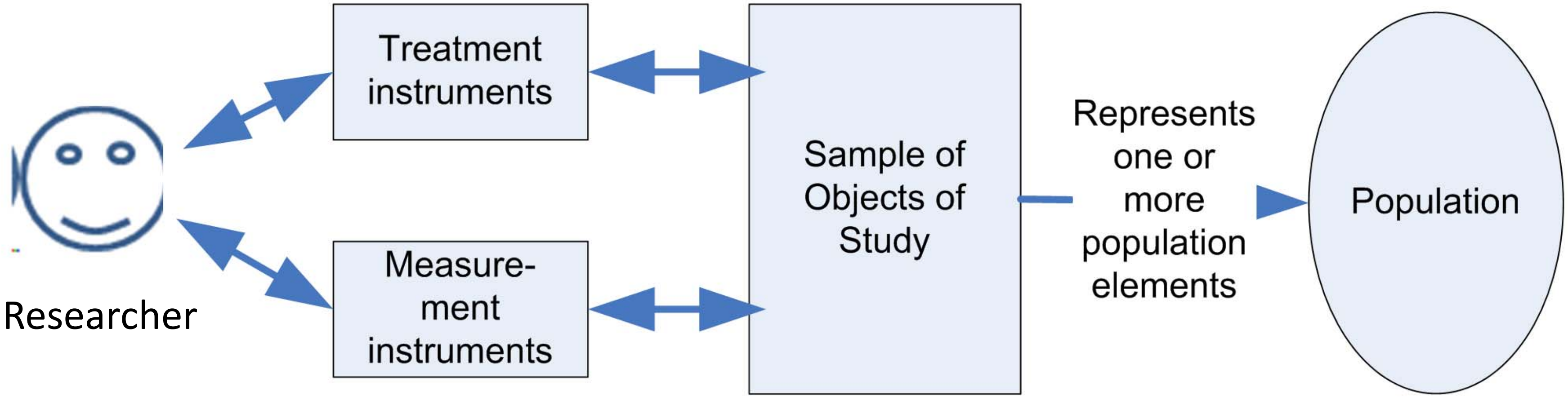
Posterior beliefs:

Updated

- Theories,
- Specifications,
- Etc.

- The goal of empirical research is to develop, test, refine change, or otherwise **update** scientific theories

The empirical research setup



You

The instruments that you need to provide input to the OoS and to collect data

The laboratory simulations or field cases that you want to study

All problems similar to the one you want to treat

Kinds of empirical research methods

	Experimental study (treatment)	Observational study (no treatment)
Sample-based: investigate samples drawn from a population, look at averages and variation, infer population parameters	• **Statistical difference-making experiment**	**Survey**
Case-based: investigate cases one by one, observe case architecture and at interaction mechanisms among components	• Expert opinion, • **Mechanism experiments,** • Technical action research	**Observational case study**

- The methods in **bold** are useful for Problem research

Surveys

- **Surveys** of instances of the problem (large sample)
    - *Survey of the use of role-based access control in large companies*
    - *Survey of the use of agile development methods in small and medium-sized companies*
- Useful to describe statistical regularities (descriptive statistics, mean, variance, correlations) in classes of problems.
- Generalization by statistical inference

- E. Babbie – *The Practice of Social Research.* 11th Edition, 2007. Chapter 9.
- C. Robson. *Real World Research.* 2nd Edition. 2002. Chapters 8 (Surveys) and 9 (Interviews)
- P. Runeson et al. *Case Study Research in Software Engineering.* 2012. Chapter 4 (Interviews and Focus Groups)

Observational case studies

- **Observational case study** of instances of an implementation or problem (small sample)
  - *Case study of power politics in the decision about acquisition of an ERP system*
  - *Case study of problems with effort estimation of project managers in one company*
  - *Field study of the behavior of elderly at home*
- Useful to describe implementations and problems in detail, and understand the mechanics and reasons behind their effects.
- Generalization by analogy

- Chapter 17

Single-case mechanism experiments

- In a **single-case mechanism experiment,** we test a social or technical system
  - *Software testing*
  - *Investigating a patient*
  - *Simulation of a real-world system*
  - *Penetration-testing the security of existing systems*
- Useful to describe the behavior of implemented technology, and to understand this in terms of underlying mechanisms
- Generalization by analogy
- Chapter 18

Statistical difference-making experiments

- In **statistical difference-making experiments**, we investigate whether in a sample, a difference in an independent variable X makes a difference to a dependent variable Y that can be generalized to the population.
  - *Apply several input scenarios to a company network and compare average behavior in scenarios with and without these inputs*
  - *Treatment group/control group experiment with software engineers to test their comprehension of UML diagrams*
- Generalization by statistical inference
- Chapter 20

Assignment chapter 5

- Drenthen (2014) - *Towards continuous delivery in system integration projects*
- Schoutsen (2012) - *Fraud detection within Medicaid*
- Van der Graaf (2012) - *EPR in Dutch hospitals-a decade of changes*
- Page 15 in Q&A

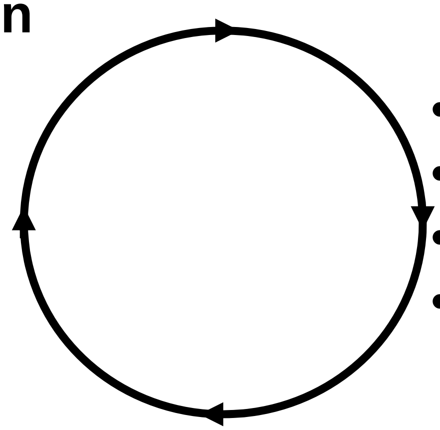
6. Requirements Specification

Main points chapter 6 Requirements specification

- **Requirements** are desired properties of a treatment for which there is a stakeholder budget
- Must be motivated by **contribution argument**
  - (context assumptions) X (artifact requirements) contribute to (Stakeholder goals)
- **Functional requirements** are desired functions
- **Nonfunctional requirements** (quality properties)
  - Accuracy, efficiency, security, reliability, usability, …
- Requirements may have to be operationalized
  - **Indicator** is measurable variable: measurable property
  - **Norm** is desired range of values of an indicator: measurable requirement

Engineering cycle

! = Action
? = Knowledge question



Design implementation

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Conceptual problem framework?
- Phenomena? Causes, mechanisms, reasons?
- Effects? Positive/negative goal contribution?

Treatment design

- Specify requirements!
- Requirements contribute to goals?
- Available treatments?
- Design new ones!

Design validation

- Context & Artifact → Effects?
- Effects satisfy Requirements?
- Trade-offs for different artifacts?
- Sensitivity for different Contexts?

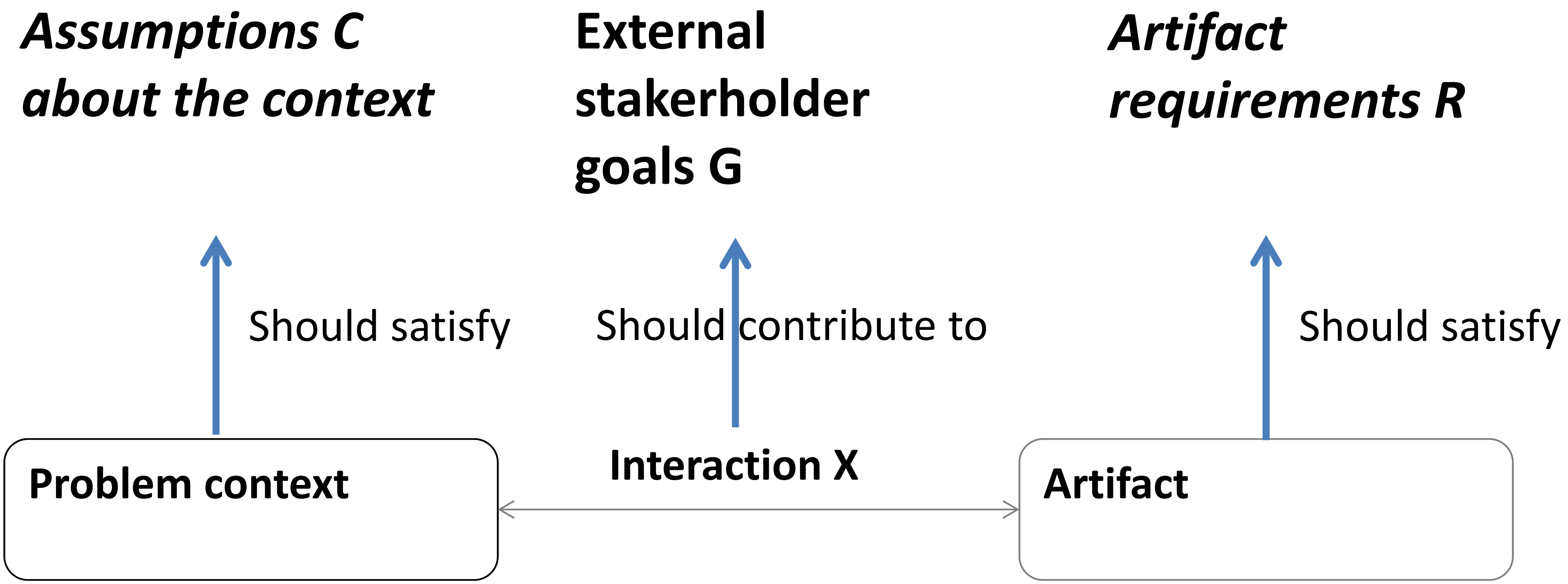
6.1 Requirements

- **Requirements** are desired properties of the treatment
  - Stakeholder goals are what the stakeholder wants to achieve
  - Requirements are what the developer must achieve
    - Special kind of goal

- Requirements cannot be just “elicited” from stakeholders
  - We do not know what we want
- Research projects may have very vague requirements
  - *See if you can do this (“existence proof”)*
  - *See if you can do this better (e.g. better execution time)*

6.2 Contribution arguments

Assumptions, requirements, goals



Assumptions C about the context

External stakerholder goals G

Artifact requirements R

Should satisfy

Should contribute to

Should satisfy

Problem context

Interaction X

Artifact

Contribution argument

- *(Context assumptions C) AND (Requirements R) IMPLY (contribution to stakeholder goal G)*

Examples

- *Ucare contribution argument*
  - *(assumptions about patient behavior & desires, IT infrastructure of home for the elderly, national communication infrastructure, third-party services) AND (requirements on mobile health care support technology) IMPLY (reduce health care cost, improved health service)*
  - *We need to evaluated systems **after** transfer to practice to see if this argument is correct!*

6.3 Kinds of requirements

Classifications of requirements

- By stakeholder (Who wants it? Whose goals are served by it?)
- By priority (How strong is the desire?)
- By urgency (How soon must it be available?)
- By aspect (What is the requirement about? Which property?)

Kinds of artefact requirements (ISO 9126)

- A **function** is a terminating part of the interaction that provides a service to some stakeholder
- **Quality properties** (a.k.a. "**nonfunctional properties**")
  - Utility ("suitability")
  - Accuracy
  - Interoperability
  - Security
  - Compliance
  - Reliability
  - Usability
  - Efficiency (time or space)
  - Maintainability
  - Portability

- These are properties of functions
- They usually have global implications for artifact components and architecture

Examples

- *Ucare*
  - *Functions*
    - *Medicine dispensing*
    - *Blood pressure monitoring*
    - *Agenda*
    - *Remote medical advice*
  - *Usable by elderly and medical personnel*
  - *Reliable*
  - *Safe*
  - *Cheap*

6.3 Indicators and norms

Operationalization

- Some properties cannot be measured directly
    - *Usability, maintainability, security, …*

- **Operationalize** them:
    - Define them in terms of one or more indicators that *can* be measured
- An **indicator** is a variable that can be measured
    - In software engineering, often called a ***metric.***

Some examples of indicators

- *Utility indicator: Opinion of stakeholder about utility*
- *Accuracy indicator: domain dependent, e.g. spatial resolution*
- *Interoperability indicator: effort to realize interface with a system*
- *Security indicators: availability, compliance to standards*
- *Compliance indicator: expert opinion about compliance*
- *Reliability indicators: mean time between failure, time to recover*
- *Usability indicators: effort to learn, effort to use*
- *Efficiency (time or space) indicators: execution time, disk usage*
- *Maintainability indicators: effort to find bugs, effort to repair, effort to test*
- *Portability indicators: effort to adapt to new environment, effort to install, conformance to standards*

See also http://en.wikipedia.org/wiki/Software_quality#Measurement

Norms

- Once we have defined indicators (“metrics”), we can operationalize requirements by means of norms

- A **norm** is a desired range of values of an indicator
  - *Average effort to learn (indicator) is less that 30 minutes (norm)*
  - *Accuracy (indicator) is better than 1 degree (norm)*
  - *Function F (indicator) must be present (norm)*
    - *When it is time to dispense a medicine, the dispenser sends an alert to the ipad*
    - *If dispensing button is pushed, the dispenser releases medicine according to protocol defined for the patient*

Assignment chapter 6

- Drenthen (2014) - *Towards continuous delivery in system integration projects*
- Zarghami (2013) – *Middleware for the internet of things*
- Page 20 in Q&A

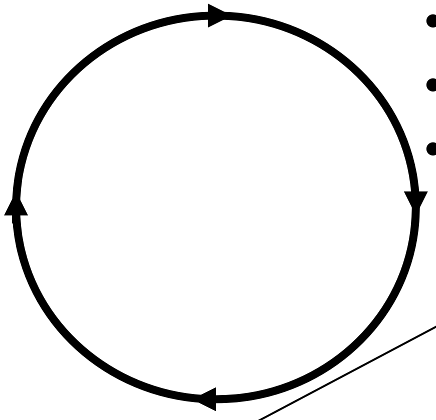
7 Treatment Validation

Main points chapter 7
Treatment validation

- Validation is a prediction problem
  - What would be the effect of artifact in context?
  - Trade-offs in design of artifact?
  - Sensitivity to changes in context?
  - Satisfaction of requirements?
- Use validation models to build a design theory of A x C;
- Then use design theory to do predictions
- Research methods
  - Expert opinion
  - Single-case mechanism experiments
  - Statistical difference-making experiments
  - Technical action research
- Scale up from idealized to practical conditions

! = **Action**
? = **Knowledge question**

Engineering cycle



Design implementation

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Conceptual problem framework?
- Phenomena?
  - Causes, mechanisms, reasons?
  - Effects?
  - Positive/negative goal contribution?

Design validation

- Context & Artifact → Effects? Why?
- Trade-offs for different artifacts? Why?
- Sensitivity for different Contexts? Why?
- Effects satisfy Requirements? Why?

Treatment design

- Specify requirements!
- Requirements contribute to goals?
- Available treatments?
- Design new ones!

7.1 The validation research goal

- *Ucare requirements*
  - *Functions*
    - *Medicine dispensing*
    - *Blood pressure monitoring*
    - *Agenda*
    - *Remote medical advice*
  - *Usable by elderly and medical personnel*
  - *Reliable*
  - *Safe*
  - *Cheap*

- To get answerable research questions,
- we need to operationalize the requirements!

- *Validation research questions*
  - *Functions*
    - *Does it perform the medicine dispensing functions?*
    - *Does it perform the blood pressure monitoring functions?*
    - *Etc.*
    - *Etc.*
  - *Is it usable by elderly and medical personnel?*
  - *Is it reliable?*
  - *Is it safe?*
  - *Is it cheap?*

Follow-up questions:

- *Does this satisfy our requirements?*
- *What if we change the design?*
- *What if we vary the context?*

7.2 Validation models

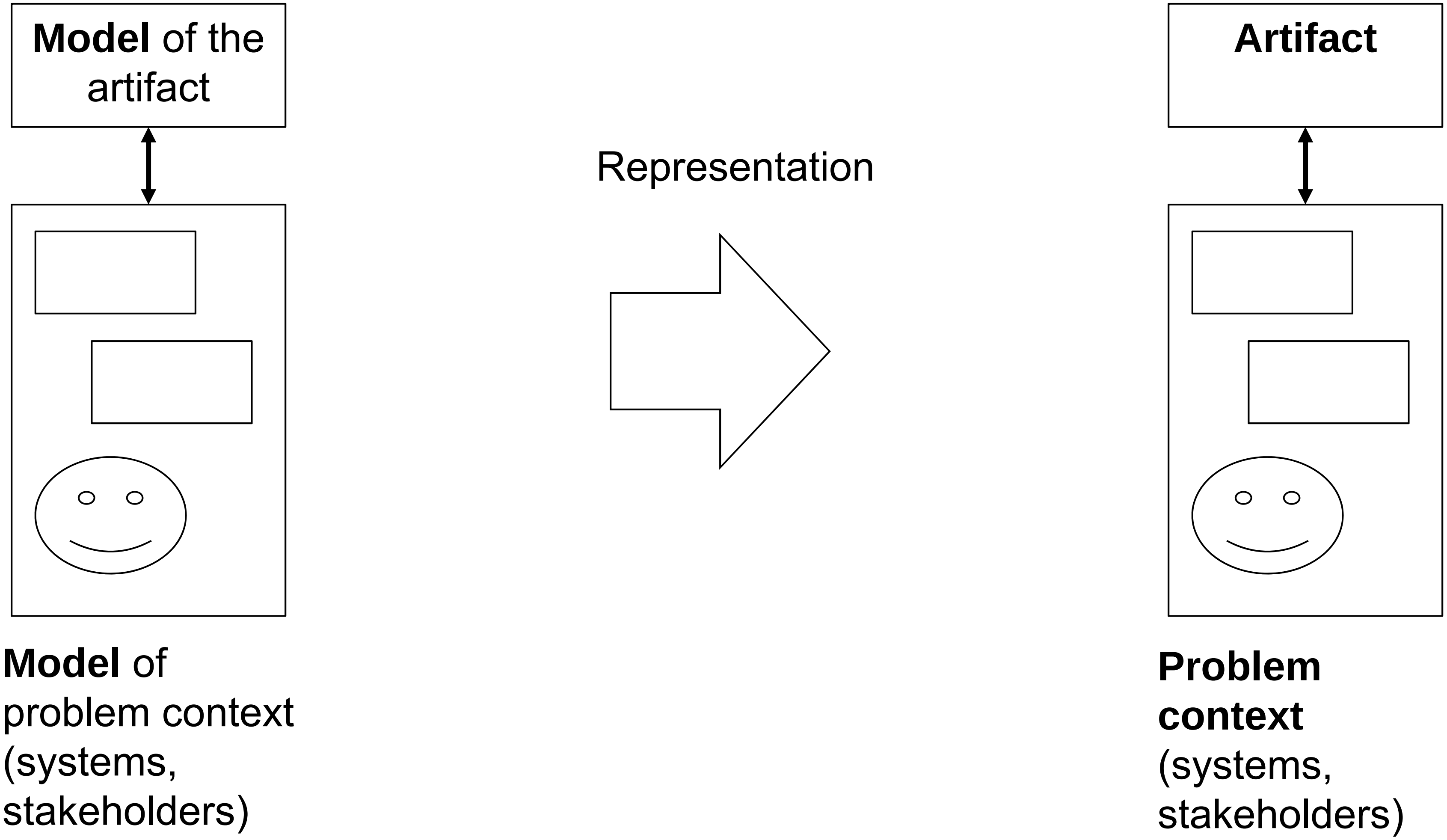
The fundamental problem of validation

- We investigate the artifact outside its natural implementation context
- The artifact has not been implemented yet.
  - It has not been transferred to the real-world problem context yet

- So we study it in the lab
- Or we do a pilot study in the real world

These are more or less realistic models of a real-world implementation

Validation models



Model of the artifact

Model of
problem context
(systems,
stakeholders)

Representation

Artifact

**Problem
context**
(systems,
stakeholders)

What is a model?

- An **analogic model** is an entity that represents entities of interest, called its **targets,**
- in such a way that questions about the target can be answered by studying the model.
- Examples
  - http://en.wikipedia.org/wiki/MONIAC_Computer
  - http://en.wikipedia.org/wiki/Scale_model
  - http://en.wikipedia.org/wiki/Miniature_wargaming
  - http://en.wikipedia.org/wiki/Simulation

Example validation models

- *A software prototype interacting with a simulated environment*
- *A class of students using a new software engineering method in a project that simulates a real-world project*
- *A researcher using an experimental method to solve a real-world problem*
- *Ucare*
  - *Nurses imagining how the system would function*
  - *Elderly using a prototype in their home*

Similarity

- How reliable is the generalization from the validation models to the real-world implementations?

- Positive analogy: Properties known to be similar
  - Should support transfer of conclusions about the model to conclusions about the target
- Negative analogy: Properties known to be different
  - Should not block the transfer of conclusions

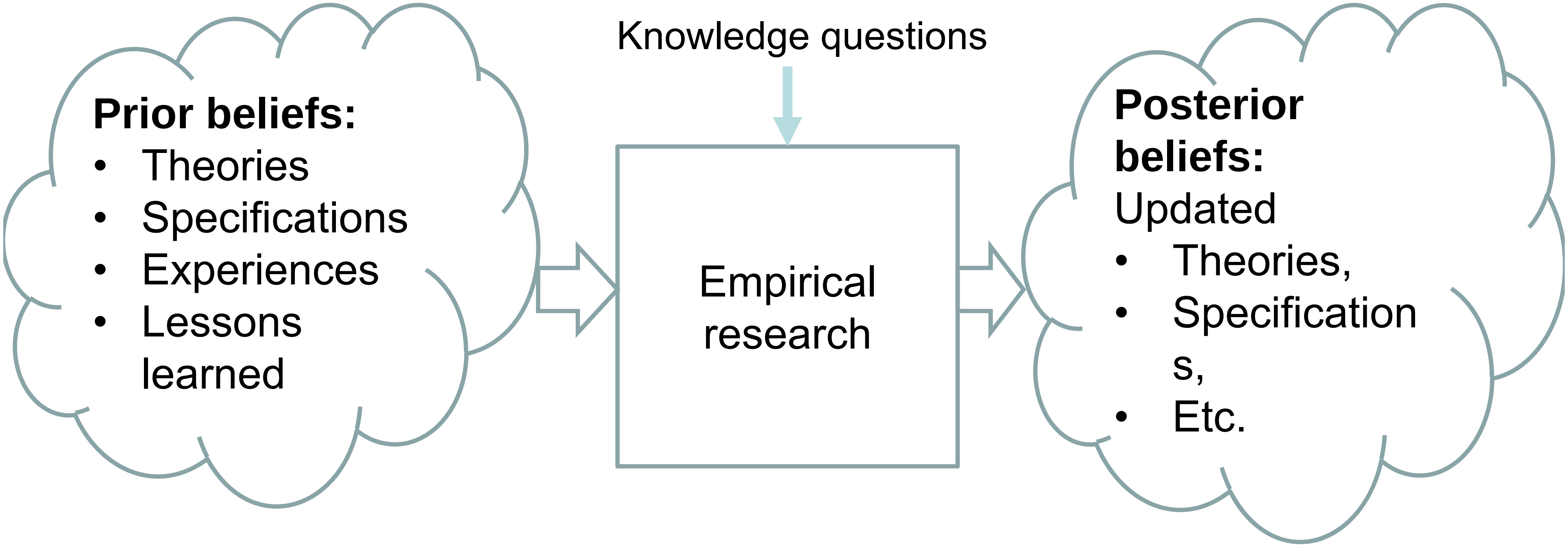
7.3 Design theories

Design theories

- Design theory = a belief that there is a pattern in the interaction between the artifact and the context, tested by experiment, critically analyzed by peers

- *Design theory of the Ucare system, developed based on field tests:*
  - *The system helps elderly take their medicine, but not necessarily on time*
  - *Elderly may not use the Ucare functions but love to use the Skype function of the ipad*
  - *To provide reliable service, service providers must align the details of their interfaces as well as their maintenance procedures*

7.4 Research methods



Prior beliefs:
- Theories
- Specifications
- Experiences
- Lessons learned

Knowledge questions

Empirical research

Posterior beliefs:
Updated
- Theories,
- Specifications,
- Etc.

Kinds of empirical research methods

- The methods in bold are useful for validation research

Kinds of empirical research methods

	Experimental study (treatment)	**Observational study (no treatment)**
Sample-based: investigate samples drawn from a population, look at averages and variation, infer population parameters	• **Statistical difference-making experiment**	Survey
Case-based: investigate cases one by one, observe case architecture and at interaction mechanisms among components	• **Expert opinion,** • **Mechanism experiments,** • **Technical action research**	Observational case study

- The methods in **bold** are useful for validation research

Expert opinion

- Researcher asks practitioners about perceived usability and utility of new artifact in the contexts that they know first-hand.
  - Interview and/or
  - Questionnaire and/or
  - Focus group
- Purpose is to weed out unrealistic ideas.
- Example
  - *Expert opinion of nurses about U-Care functionality*

Single-case mechanism experiments

(a.k.a. simulations)

Mechanism experiment

- Single-case mechanism experiments are simulations, tests etc.
  1. Build a validation model
  2. Experiment with it
  3. Describe and explain results
  4. Generalize by analogy to similar cases
- Examples
  - *Testing a software prototype of ucare using your colleagues*

Technical action research

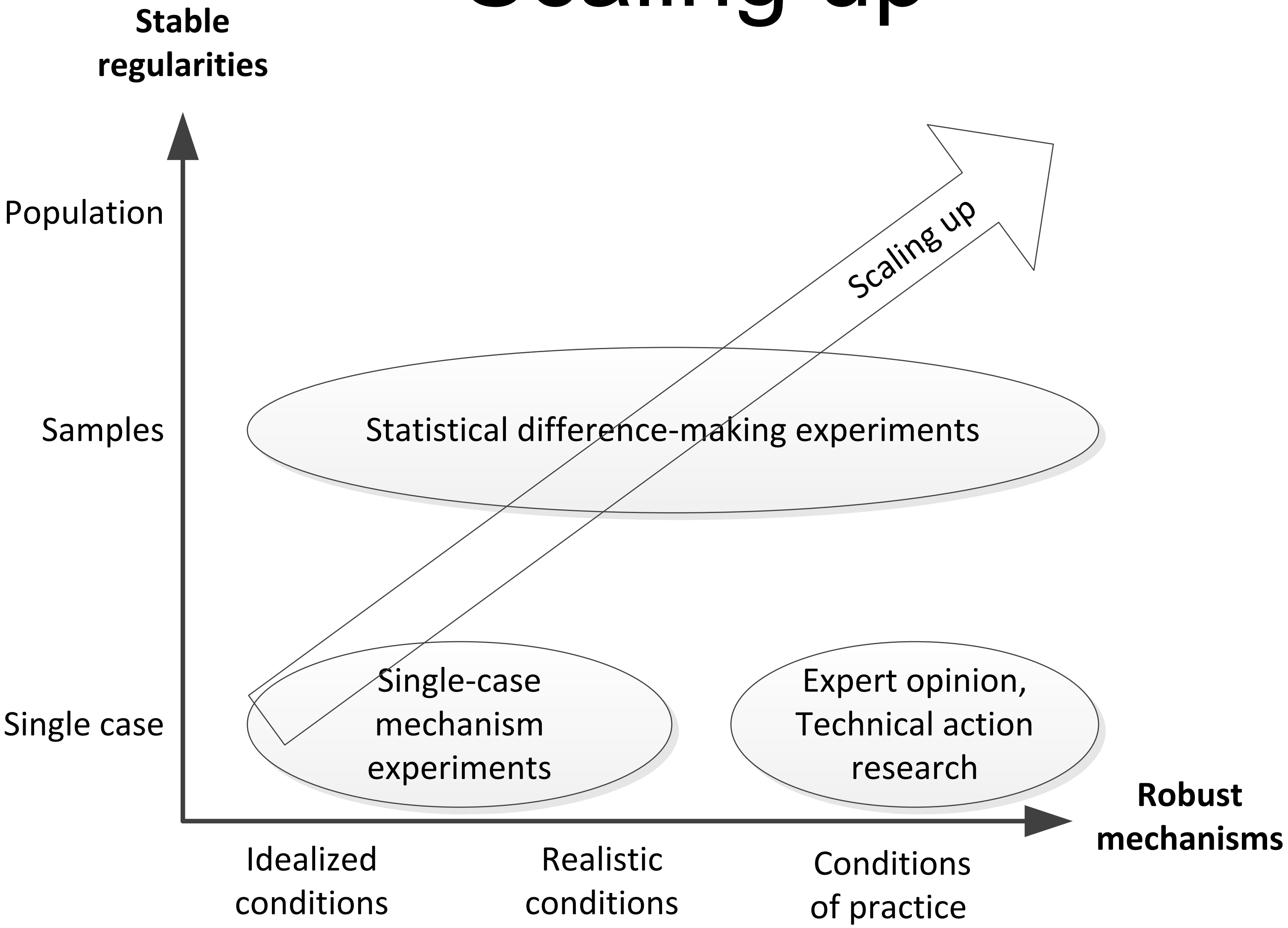
Technical action research (TAR)

- TAR
  1. Build an artifact prototype and acquire a client
  2. Treat the client's problem with the artifact
  3. Describe and explain results
  4. Generalize by analogy to similar cases
- Examples
  – *Test a prototype of Ucare with volunteers in a home for the elderly*

Statistical difference-making experiments

7.4 Scaling up

Scaling up

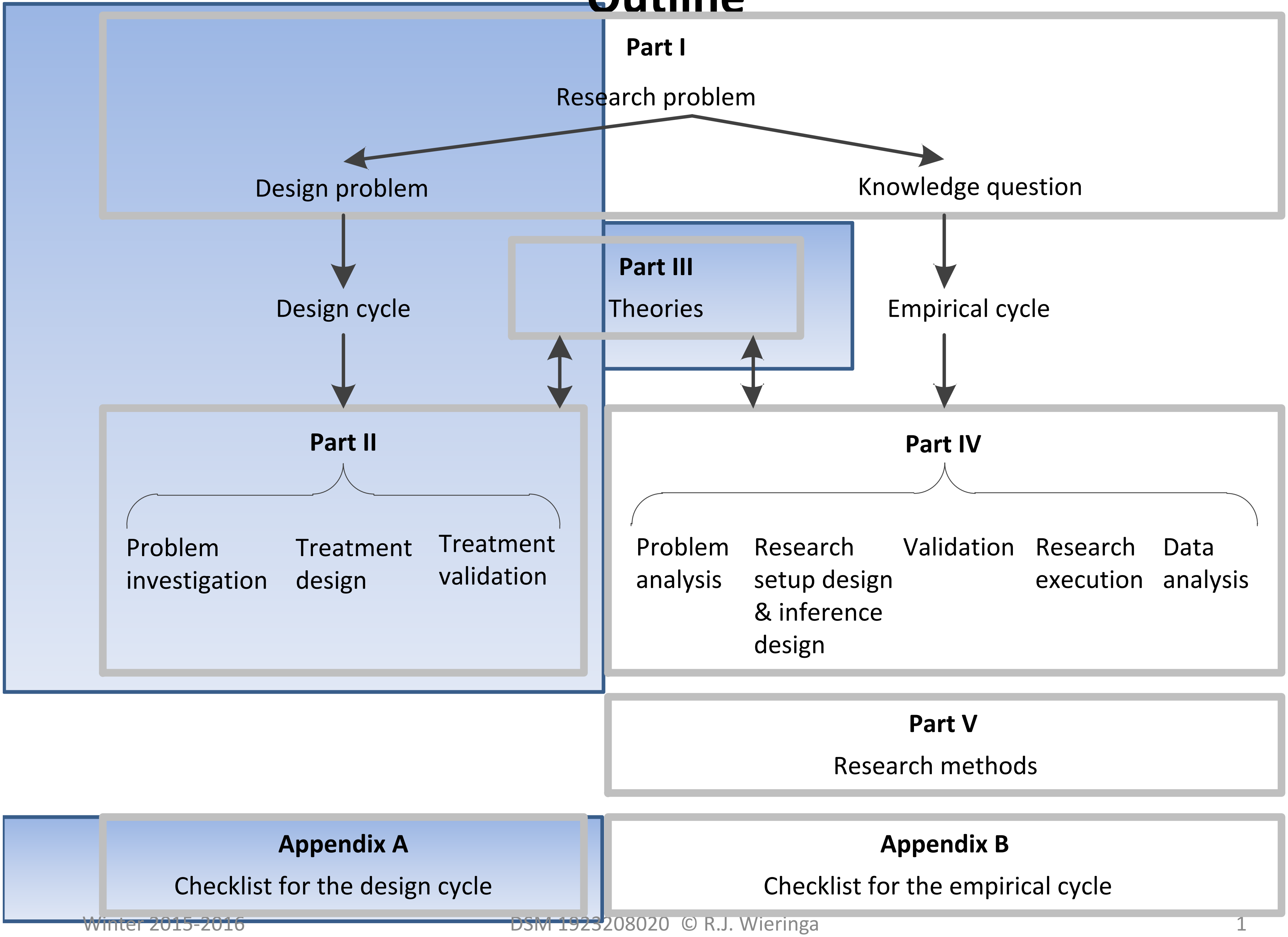


Stable regularities
Population
Samples
Single case
Scaling up
Statistical difference-making experiments
Single-case mechanism experiments
Expert opinion, Technical action research
Robust mechanisms
Idealized conditions
Realistic conditions
Conditions of practice

Assignment chapter 7

- Broenink (2014) - *Finding Relations Between Botnet C&Cs for Forensic Purposes*
- Schoutsen (2012) - *Fraud detection within Medicaid*
- Zarghami (2013) – *Middleware for the internet of things*
- Page 22 in Q&A

Outline



Part I

Research problem

Design problem

Knowledge question

Design cycle

Part III

Theories

Empirical cycle

Part II

Problem investigation

Treatment design

Treatment validation

Part IV

Problem analysis

Research setup design & inference design

Validation

Research execution

Data analysis

Part V

Research methods

Appendix A

Checklist for the design cycle

Appendix B

Checklist for the empirical cycle

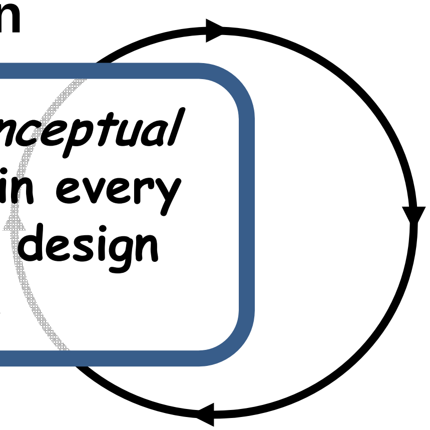
Main points chapter 8
Conceptual frameworks

- A **conceptual framework** is a set of definitions of concepts.
  - **Architectural frameworks** allow you to talk about architectures, components & capabilities, and mechanisms that produce system-level phenomena
  - **Statistical frameworks** allow you to talk about populations, variables and probability distributions
  - **Mixed** frameworks allow both
- Conceptual frameworks can be shared with the domain
- Functions of conceptual frameworks:
  - To frame, describe, generalize about, and analyze phenomena, and to specify a design.
- Constructs (i.e. concepts) are cognitive tools.
  - **Validity** w.r.t. a cognitive goal
  - Threats to construct validity: inadequate definition, construct confounding, mono-operation bias, mono-method bias

8. Conceptual frameworks

Engineering cycle

! = **Action**
? = **Knowledge question**



Design implementation

We need *conceptual frameworks* in every task of the design cycle

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Conceptual problem framework?
- Phenomena? Causes, mechanisms, reasons?
- Effects? Positive/negative goal contribution?

Treatment validation

- Context & Artifact → Effects?
- Effects satisfy Requirements?
- Trade-offs for different artifacts?
- Sensitivity for different Contexts?

Treatment design

- Specify requirements!
- Requirements contribute to goals?
- Available treatments?
- Design new ones!

8.1 Conceptual structures

a.k.a. conceptual framework

Conceptual frameworks (a.k.a. conceptual structure)

- A **conceptual framework** is a set of definitions of concepts , often called **constructs**.

- Do not confuse a **conceptual** framework (a set of definitions of concepts) with
- a **software** framework (a reusable set of libraries or classes for a software system)!

Statistical structures

- **Statistical structures:** Definitions of
  - Population;
  - (random) variables;
  - probability distributions of variables;
  - Parameters of those distributions;
  - relations among variables.
- Examples
  - *Elderly living at home; age, blood pressure, heartbeat; normal distribution, exponential distribution; distribution mean, distribution variance; correlation*
- Useful for sample-based research

Random variables

- A **(random) variable** is an observable property of population elements
- A **probability distribution** of X is a mathematical function that summarizes the probability of selecting a sample of values in a random draw from the X-Box
- **X-box** is the set of values of X on a population
- **XY-box** is the set of pairs of values of (X, Y) on a population, etc.
- **Chance model** of X:
    1. Definition of the meaning of numbers in the X-box (conceptual framework)
    2. Assumptions about probability distribution (population definition)
    3. Measurement procedure (measurement design)
    4. Sampling procedure (sampling design)

Example

- *Paper by Huynh & Miller. Population of open source web applications*
- *Random variable ImpV indicates implementation vulnerabilities.*
- *Chance model of ImpV:*
  1. *Definition: The numbers on the tickets in the ImpV-box are proportions of implementation vulnerabilities among total number of vulnerabilities in a web application. (pages 564-565)*
  2. *Assumptions: binomial distribution. The proportions of implementation vulnerabilities in different web applications are independent, and the probability that a vulnerability is an implementation vulnerability, is constant across all web applications*
  3. *Measurement procedure: Counting and classifying by a person.*
  4. *Sampling procedure: Not specified. 20 applications are listed.*

Advantages of statistical structures

Statistical structures can be used to make large-scale population properties visible

This in turn can be used to

- Describe aggregate phenomena in a sample
- Generalize from a sample to a population (sample-based)
- Estimate patterns in the population not visible at the individual level (e.g. identify needs in a population)
- Estiame variation across a population
- Estimate the effect of treatments in the population (prediction of policy impact)

Architectural structure

- **Architectural structure:** Definitions of
  - a class of technical/physical/social/digital systems;
  - components with capabilities;
  - mechanisms of interaction among components.
- Examples
  - *Mobile health monitoring system; patients, nurses, doctors, technical personnel, database server, ipad, agenda system, medicine; medical protocol, communication protocol, data retention protocol, maintenance schedule, ….*

Advantages of architectural frameworks

Architectures can be used to decompose complex problems into simpler problems

- Study a few components at a time
- Study an architecture while abstracting from internal structure of components

This in turn can be used to

- Trace phenomena to component properties (explanation, diagnosis)
- Explore the effects of putting different components together (prediction, design)
- Reason about similarity (case-based generalization)

Terminology

Architectural framework	**Statistical framework**
Class of systems	Population
System	Population element
Property of system	Variable
Anything else	Variable

Mixed structures

- Doing a case study of a population element in sample-based research:
  - *Survey of a sample of elderly in a home,*
  - *Followed by interviews of a few of them*
- Investigation a population within a case study:
  - *Case study of medical protocols and interactions in a regional health care ecosystem (hospital, care homes, family doctors, etc.)*
  - *Containing a survey of the opinions of medical personnel about these protocols*
- **Sample-based statistical studies** talk about populations, random samples, variables, and distributions
- **Case-based architectural studies** talk about systems, components, capabilities, interactions, mechanisms

8.2 Sharing and interpreting a conceptual framework

- Concepts shared by people in the domain may be adopted by researchers that investigate the domain
  - *Goal, requirement, effort, etc.*
  - Adopting these concepts in the conceptual research framework may allow additional understanding
- Concepts defined by researchers may be adopted by people in the domain
  - *(software) object program structure, agile, etc.*
  - Adopting these concepts in the domain may allow definition of additional options for action
- Concepts may even make a round trip

8.3 The functions of conceptual frameworks

Uses of a conceptual framework

- **Frame** a problem or artifact:
  - Choose which concepts to use
  - Structure the problem or artifact
- **Analyze** a problem or artifact (i.e. analyze the framework)
- **Describe** a problem using the concepts
- **Specify** an artifact using the concepts
- **Generalize** about the problem or artifact

Examples

- ***Framing:*** *talk about patients, clients, or elderly*
- ***Analyzing*** *medical protocols*
- ***Describing*** *daily routines, medicine dispensing, blood pressur measurement etc.*
- ***Specifying*** *the Ucare system using these concepts*
- ***Generalizing*** *about the usability of the system to other homes*

8.4 Construct Validity

- Conceptual structuresare not true or false
  - A definition is not a statement that is true or false
- Constructs are tools.
  - Concepts may be more or less **useful** to produce insight and options for action

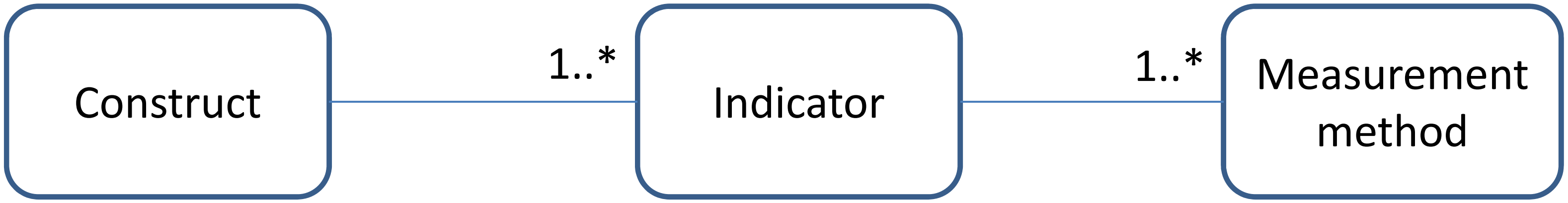
- **Construct validity** is the degree to which the application of constructs to phenomena is justified,
- taking into account their definitions, and your research goals and questions.

Threats to construct validity

- **Inadequate definition**
  - No identification and classification criterion.
  - We need to recognize an instance when we see one (classification); and we need to be able to count how many of them there are (identification)
  - *E.g. elderly, medical personnel, carer, blood pressure, heart beat, ….*
- **Construct confounding**
  - Instances may be instances of more than one population.
  - *Measuring the effect of a system on a sample of potential users*
    - *Is this a sample of enthousiastic users?*
    - *Of well-educated users?*
    - *Of users who like extra attention?*
    - *So what is the target of generalization?*

Threats to validity of operationalizations

- **Mono-operation bias**
  - Defining only one indicator for a construct
  - *E.g. measuring **maintainability** by **effort to repair a bug** only (and ignoring effort to find a bug or test the repair).*
- **Mono-method bias**
  - Indicator measured in only one way.
  - *E.g. measuring **effort to repair a bug** only by measuring the time between opening a bug tracker entry and closing it. A second way of measuring would be the analysis of time stamps in configuration management log files. A third way is to ask the programmer. Or to film the programmer.*



Assignment chapter 8

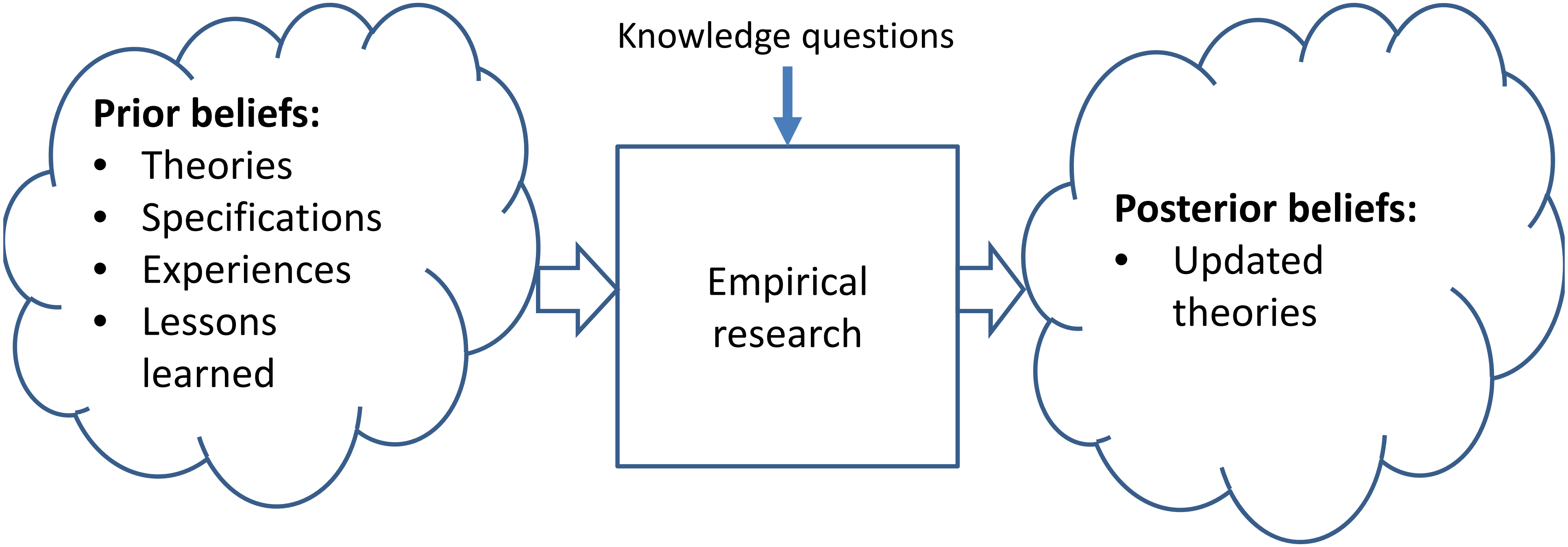
- Drenthen (2014) - *Towards continuous delivery in system integration projects*
- Van der Graaf (2012) - *EPR in Dutch hospitals-a decade of changes*
- Page 27 in Q&A

9. Scientific Theories

Main points chapter 9
Scientific theories

- **Scientific theory** is a belief about patterns in phenomena that is tested empirically and peer-reviewed critically
- Theory structure: Conceptual framework, generalizations (with a scope)
- **Design theories** have two kinds of generalizations:
  - Effect generalization
  - Requirements satisfaction generalization
- Scope of a design generalization: (design choices) x (context assumptions)
- Functions of generalizations: explain, predict, design
  - Causal, architectural, rational explanations
- Design generalizations are **usable** by a practitioner if:
  - Practitioner is capable to build/buy the artifact,
  - Recognize its context assumptions,
  - Predict effects of A x C with sufficient certainty,
  - Establish that effects contribute to stakeholder goals.

Empirical research



Knowledge questions

Prior beliefs:

- Theories
- Specifications
- Experiences
- Lessons learned

Empirical research

Posterior beliefs:

- Updated theories

- The goal of empirical research is to develop, test or refine theories

9.1 Theories

- A **theory** is a belief that there is a pattern in phenomena.

Theories in popular discourse

- Different meanings of the word ``theory’’
  - **A speculation** without basis in facts; conspiracy theories
    - *“The NSA is monitoring all my email”*
    - *’’Obama is not an American”*
  - An **unusable idealization** not applicable to the real world:
    - *“Merging two faculties reduces cost in theory, not in practice.”*
    - *“Traffic rules are fine in theory, but not on the street”.*
  - An **opinion**, usually resistant to all critique.
    - *“The Dutch won the game because the Spanish played lousily.”*
    - *“You should buy a Mac, then you will not have connection problems anymore”*

Scientific theories

- A **scientific** theory is a theory that
  - Has survived tests against experience
    - Observation, measurement
    - Possibly experiment, simulation, trials
  - Has survived criticism by critical peers
    - Anonymous peer review
    - Publication
    - Replication

- *Examples*
  - *Classical mechanics*
  - *Theory of electromagnetics*
  - *Signal theory*
  - *Theory of fermentation*
  - *Theory of cognitive dissonance*
  - ..

Theories are fallible

- All theories may be wrong!
  - Outside mathematics there is no certainty
  - Even inside math we can be wrong (Lakatos)

- To test a belief, we need
  - Empirical facts and
  - Criticism from peers
- Testing never finishes

9.2 The structure of scientific theories

The structure of scientific theories

1. **Conceptual framework (a.k.a. conceptual structure)**
   - *E.g. The concepts of beamforming, of multi-agent planning, of data location compliance*
2. **Generalizations** stated in terms of these concepts, that express beliefs about patterns in phenomena.
   - *E.g. relation between angle of incidence and phase difference,*
   - *Statement about delay reduction on airports.*
3. **Scope** of the generalizations. Population, or similarity relation
   - *E.g. all correctly built antenna arrayse receiving plane waves in a narrow bandwidth*
   - *All large airports.*

Examples

- *Classical mechanics*
  - *Conceptual framework: point mass, velocity, momentum, etc.*
  - *Generalizations: Laws of Newton*
  - *Scope: universal, but velocity not close to c.*
- *Theory of cognitive dissonance*
  - *Conceptual framework: beliefs, dissonance, resolution*
  - *Generalization: People seek consistency among their cognitions. They resolve this by creating comfortable beliefs.*
  - *Scope: all human beings*

The structure of **design** theories

1. **Conceptual framework** to specify artifact and describe context
2. **Generalizations**
   - Artifact specification X Context assumptions → Effects
   - Effects satisfy a requirement to some extent
3. The **scop**e: defined by constraints on artifact design, and assumptions about the context

Examples

- *Signal theory about interaction between antenna array (artifact) and plane waves (context)*
  - *Conceptual framework: wave, plane wave, wavefront, frequency, wave length, bandwidth, noise, … antenna array, …*
  - *Generalizations:* $\varphi = 2\pi \left(\frac{d}{\lambda}\right) \sin\theta.$
  - *Scope: only for plane wavefronts, narrow bandwidth*
- *Agile requirements engineering (artifact) for SME's (context)*
  - *Conceptual framework: RE, agile, SME*
  - *Generalization: SME's do not put a client on the project because of their limited budget*
  - *Scope: all agile projects done for SME's*

9.3 The functions of scientific theories

- Functions of a conceptual framework
  - **Framing** a problem or artifact
  - **Describe** a problem or **specify** an artifact
  - **Generalize** about the problem or artifact
  - **Analyze** a problem or artifact (i.e. analyze the framework)
- Functions of generalizations
  - Explanation
  - Prediction
  - Design

Core cognitive function

Core function for design

Need usable prediction

Explanations

- An **explanation** is hypothesis about how a phenomenon came about.
  - **Causal explanations** explain the occurrence of an event by the occurrence of an earlier event
  - **Architectural explanations** explain the existence of a causal relationship by the mechanisms that produced it
  - **Rational explanation**s explain the behavior of actors by their goals.

Causal explanations

- Causal explanations say that an earlier event **made a difference** to a current event.
- *“Programming effort is low* ***because*** *we use UML”*
  - *The earlier switch to UML resulted in the current reduction of programming effort*
  - *“If we had not switched to UML earlier, our current programming effort would have been higher.”*

- Causal explanations hypothesize something about the difference between the current world and another, possible, world.
  - Causality is unobservable.
  - May be nondeterministic

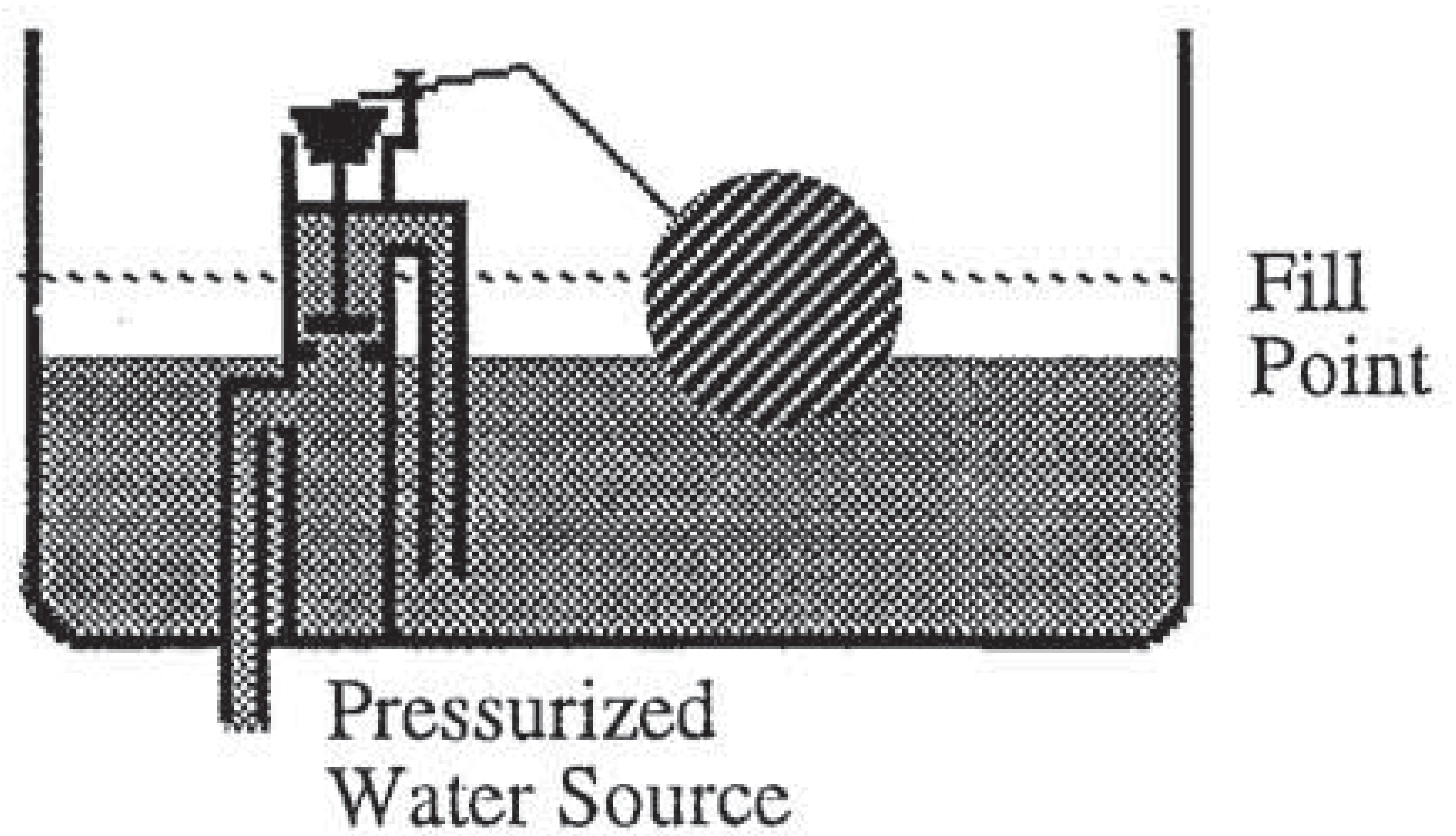
Architectural explanations

- **Architectural explanations** explain the existence of a causal relationship by the mechanisms that produced it
  - An architecture of a system is a collection of **components,** with **capabilities,** and relationships by which they can **interact.**

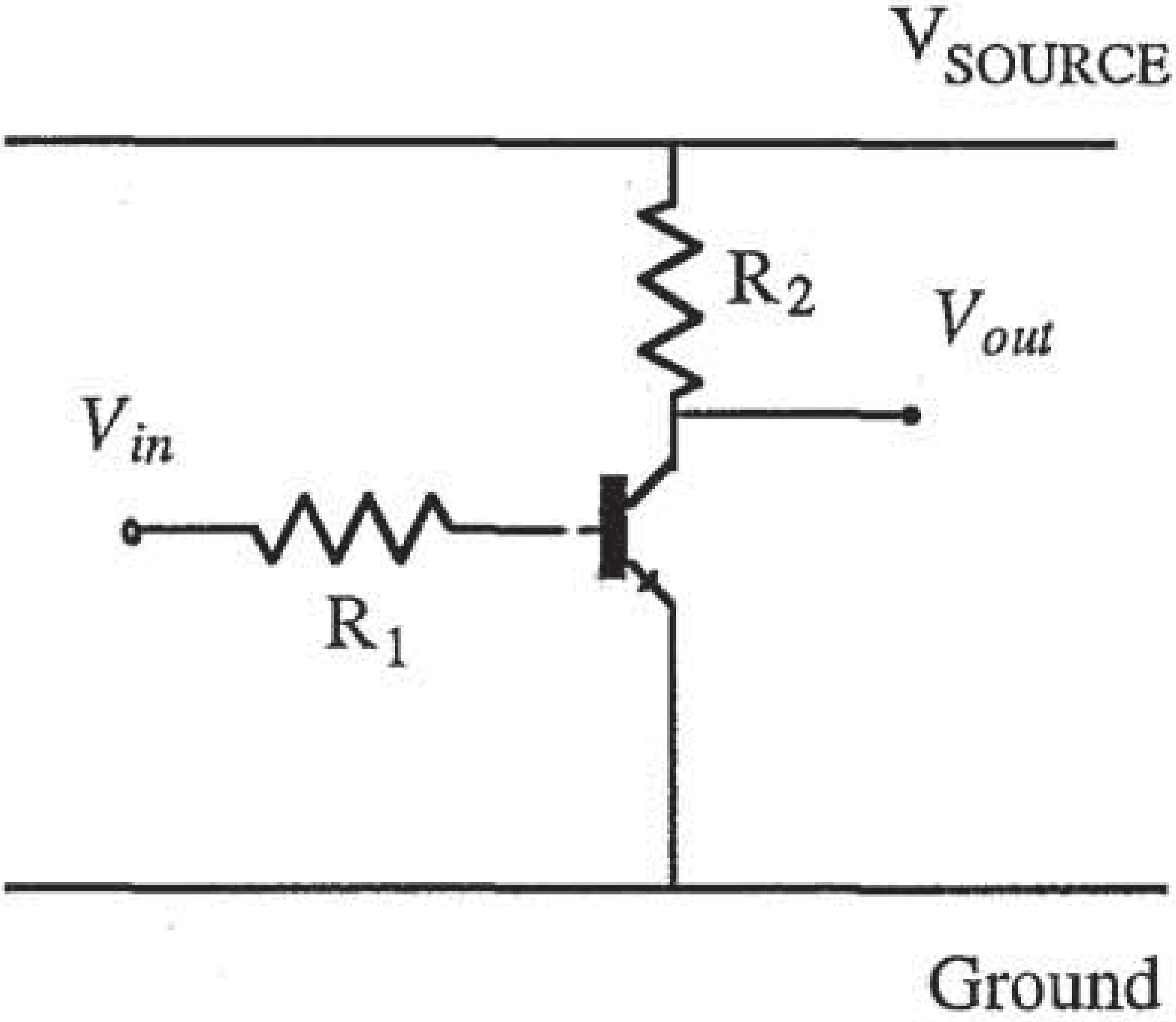
– The interactions by which a stimulus produces a response is called the **mechanism** by which the response is produced.

  - May be nondeterministic

- Architectural explanations are common in technical sciences, physics, chemistry, biology, sociology, psychology, …

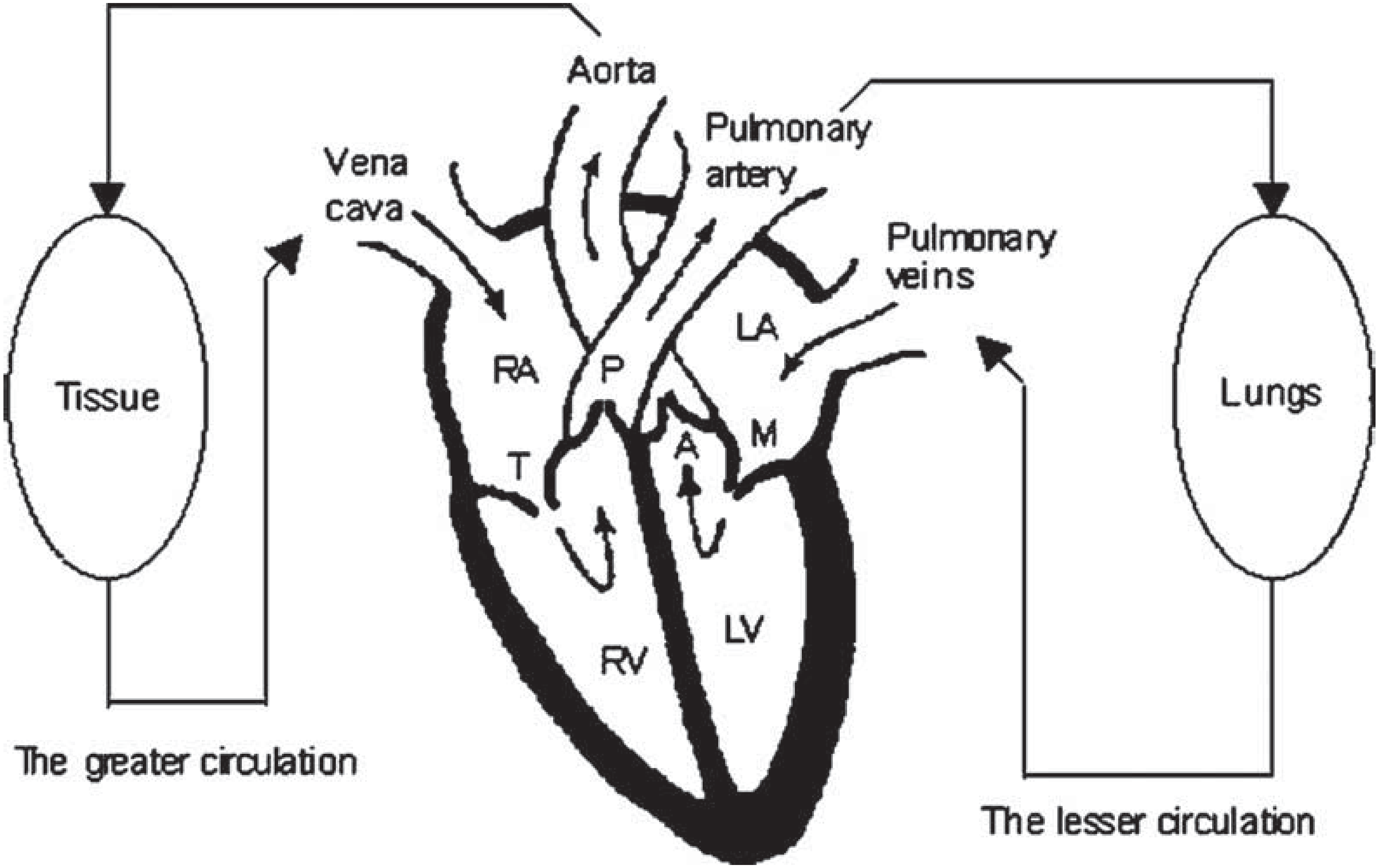


- Glennan - ``Mechanisms and the nature of causation''. 1996

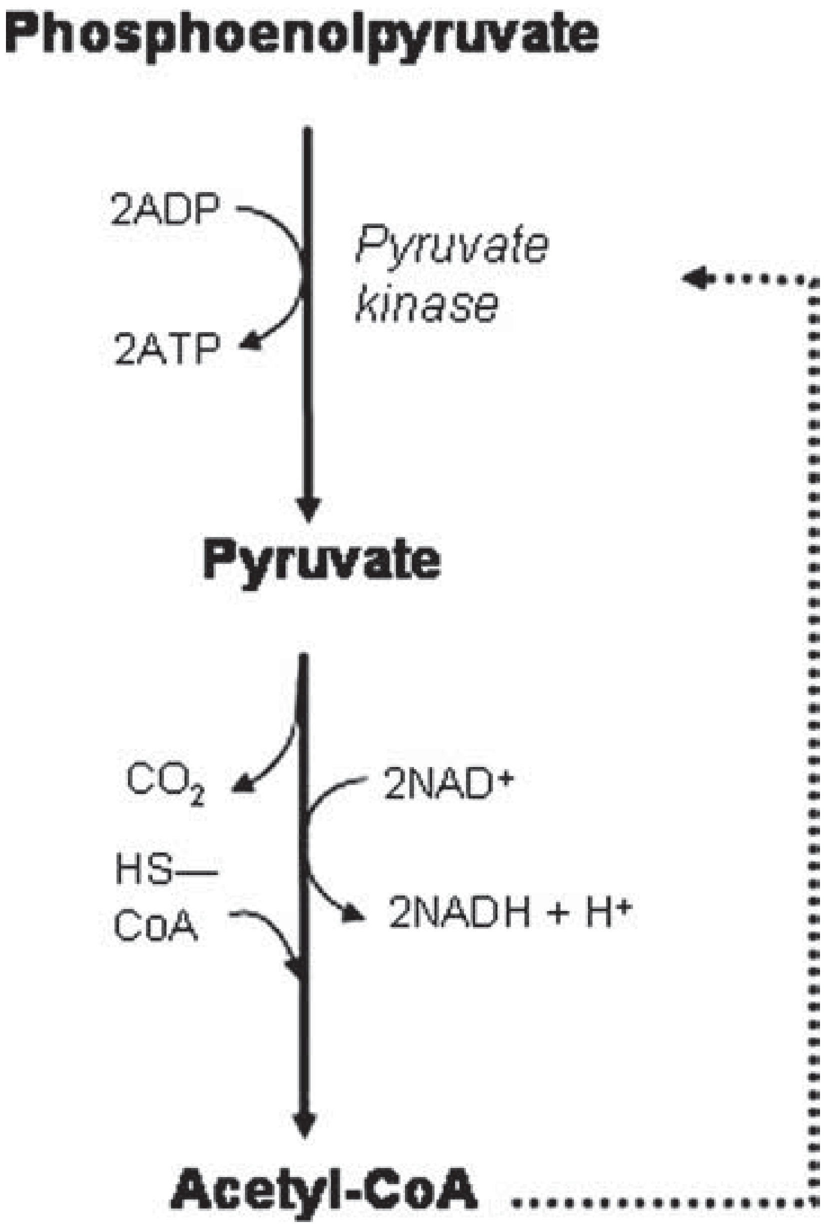


A voltage
switch

- Glennan - ``Mechanisms and the nature of causation''. 1996



- Bechtel & Abrahamsen – ``Explanation; a mechanistic alternative.'' 2005



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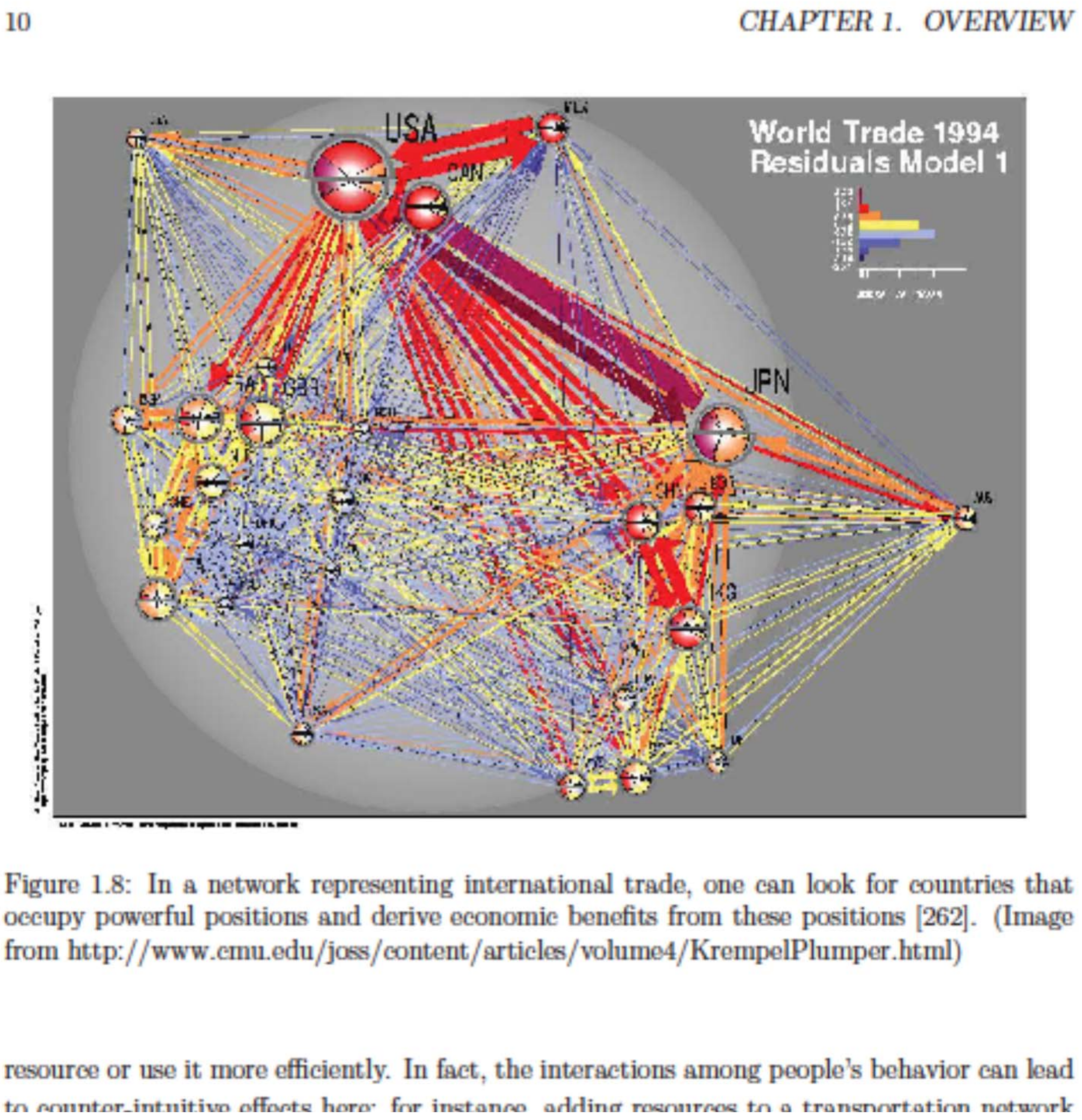
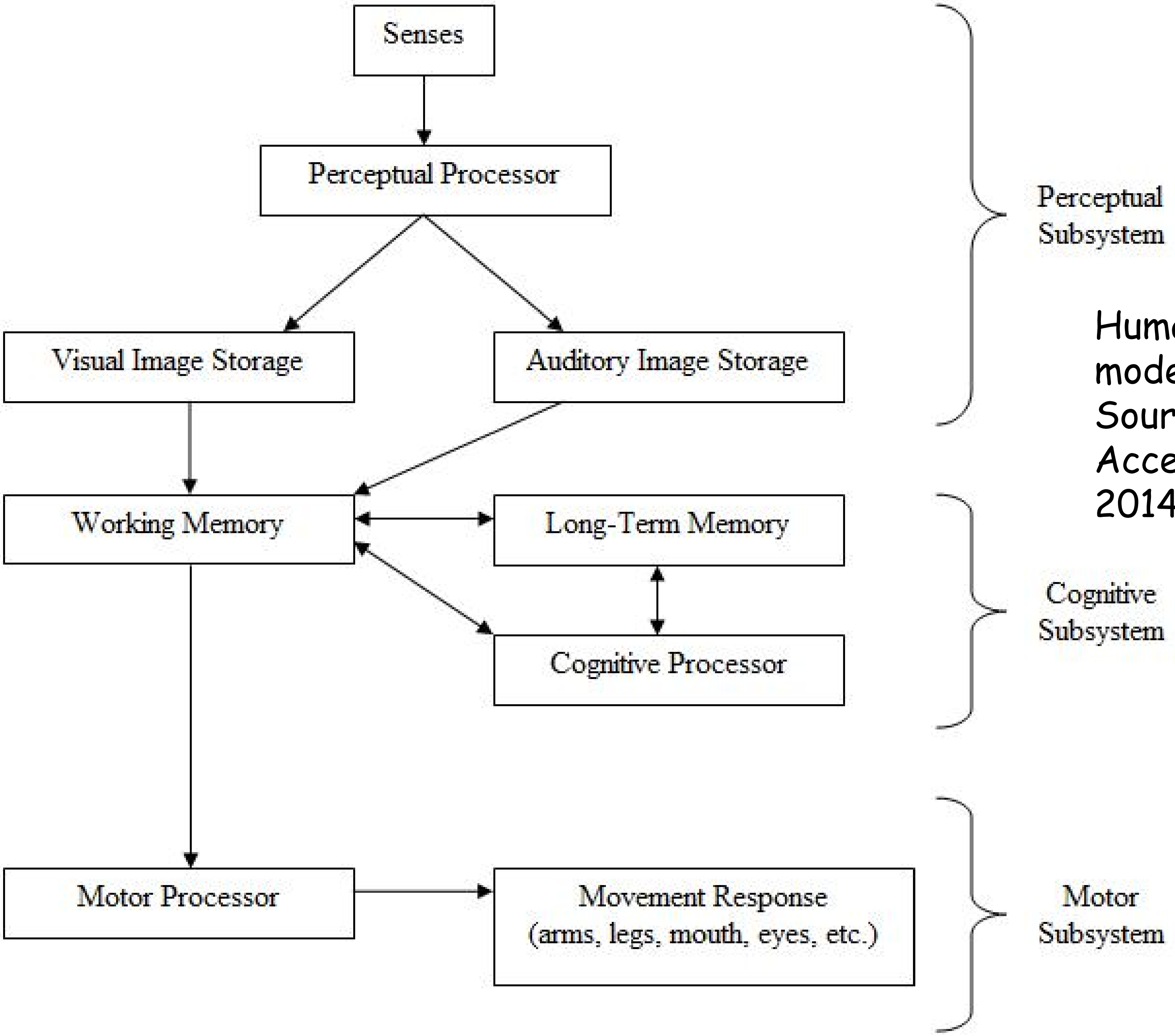


10 CHAPTER 1. OVERVIEW

Figure 1.8: In a network representing international trade, one can look for countries that occupy powerful positions and derive economic benefits from these positions [262]. (Image from http://www.cmu.edu/joss/content/articles/volume4/KrempelPlumper.html)

resource or use it more efficiently. In fact, the interactions among people's behavior can lead to counter-intuitive effects here: for instance, adding resources to a transportation network



Human processor model
Source: Wikipedia
Accessed 7 dec 2014

- Causal and architectural explanations must be mutually consistent
  - Causal: Y occurred because earlier, X occurred and this made a difference to Y
  - Architectural: Stimulus X produces response Y due to mechanism Z
- Examples
  - *Light switch*
  - *Mechanism of action of a drug* *http://en.wikipedia.org/wiki/Mechanism_of_action*
  - *Principle of operation of a pump, of a transformed, of an airplane, etc. etc.*

- To give a causal explanation you do not have to know the underlying mechanism.
- If you know the mechanism, you can give an architectural as well as causal explanation

Rational explanations

- **Rational explanation**s explain the behavior of actors by their goals.
- Architectural explanation for social systems that include rational actors
- Example
  - *In divisionalized bureaucracies, development of a system that reduces the ownership of data and processes by managers, will be sabotaged by those managers.*
  - *Using Ucare, elderly may not follow the blood pressure measurement protocol anymore because they measure after waking up, and they may wake up any time after 03:00 hours.*

The functions of scientific theories

- Functions of a conceptual framework
  - **Framing** a problem or artifact
  - **Describe** a problem or **specify** an artifact
  - **Generalize** about the problem or artifact
  - **Analyze** a problem or artifact (i.e. analyze the framework)
- Functions of generalizations
  - Explanation ← Core cognitive function
  - Prediction ← Core function for design
  - Design ← Need usable prediction

Predictions

- A prediction is a claim that something will happen in the future
- If you can describe a stable pattern in the phenomena, then you can predict
  - *In all our test runs, one iteration took less than 7.2ms.*
  - *In CMM 3 organizations developing embedded software, defect removal effectiveness is 98%.*
  - These descriptions are statistical generalizations, assumed to be stable across the population, and do not provide an explanation

Explanation and prediction

- Many explanations are too incomplete to be used as predictions
  - *Explanations of the outcome of a football match*
- Some explanations can be used for prediction too
  - *Most examples of explanations given so far!*

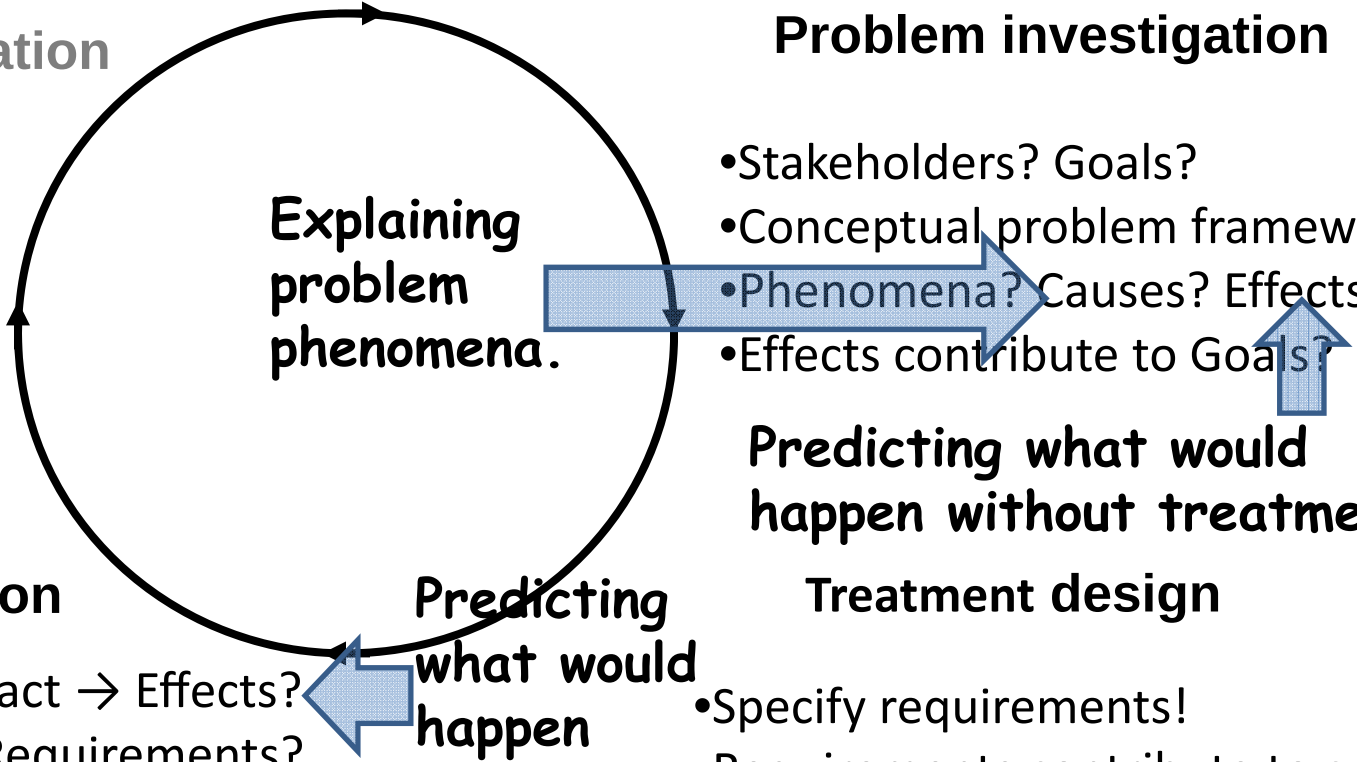
The functions of scientific theories

- Functions of a conceptual framework
  - **Framing** a problem or artifact
  - **Describe** a problem or **specify** an artifact
  - **Generalize** about the problem or artifact
  - **Analyze** a problem or artifact (i.e. analyze the framework)
- Functions of generalizations
  - Explanation
  - Prediction
  - Design

Core function for design

Need usable prediction

The role of theories in design



Design implementation

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Conceptual problem framework?
- Phenomena? Causes? Effects?
- Effects contribute to Goals?

Explaining problem phenomena.

Predicting what would happen without treatment.

Design validation

- Context & Artifact → Effects?
- Effects satisfy Requirements?
- Trade-offs for different artifacts?
- Sensitivity for different Contexts?

Predicting what would happen with treatment.

Treatment design

- Specify requirements!
- Requirements contribute to goals?
- Available treatments?
- Design new ones!

Usability of design theories

- When is a design theory

  Context assumptions X Artifact design → Effects

  usable by a practitioner?

  1. He/she is capable to recognize Context Assumptions
  2. and to acquire/build and use the Artifact,
  3. effects will indeed occur when used, and
  4. Effects will contribute to stakeholder goals

- Practitioner has to asses the risk that each of these fails

Ucare

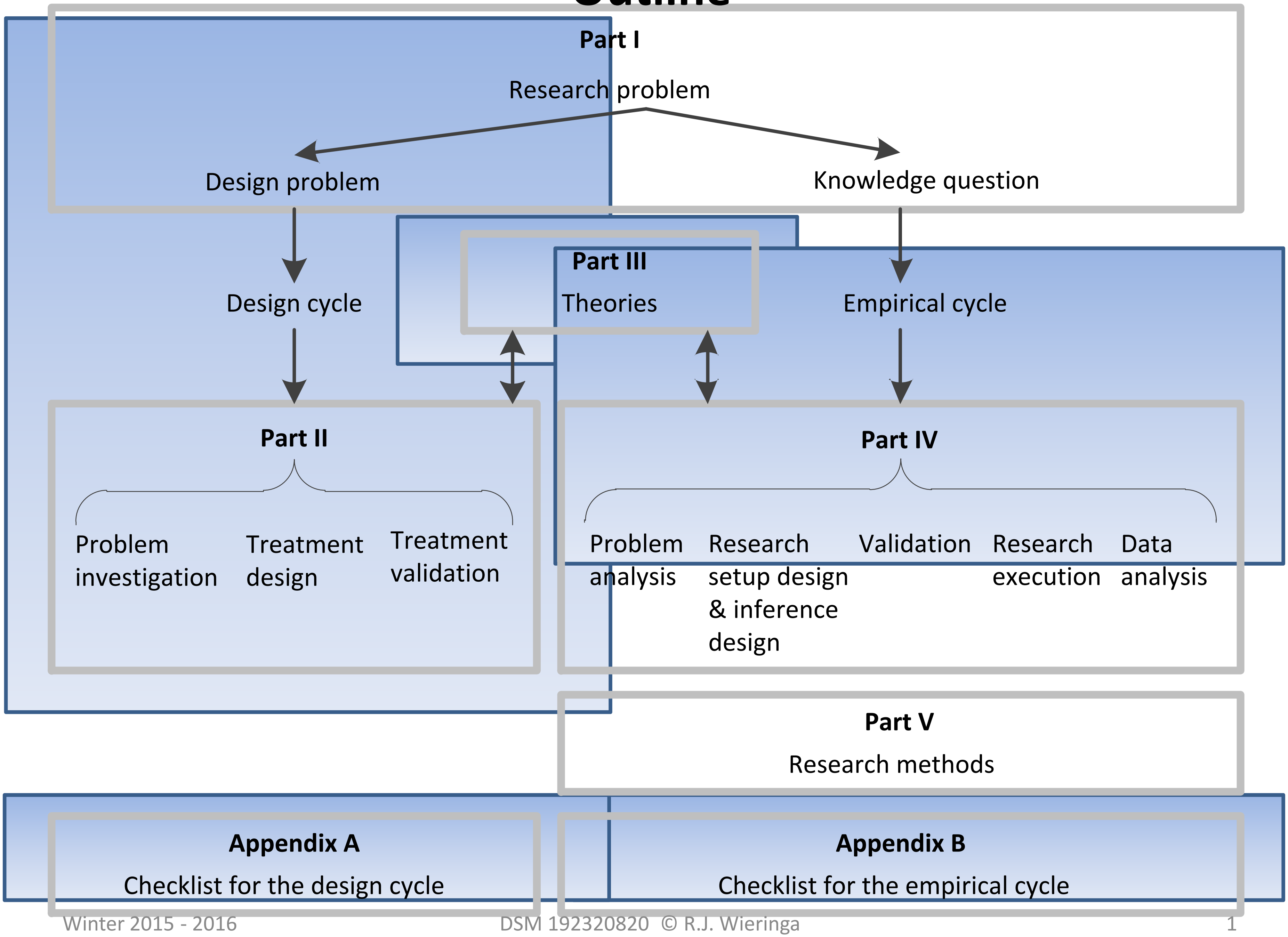
- *(Assumptions about elderly and their context) X (Ucare specification) → (Cheaper and better home care)*
- *Usable by a practitioner?*
  1. *He/she is capable to recognize Context Assumptions*
  2. *And to acquire/build and use the Artifact,*
  3. *Effects will indeed occur when used, and*
  4. *Effects will contribute to stakeholder goals*

- *What are the risks?*

Assignment chapter 9

- Drenthen (2014) - *Towards continuous delivery in system integration projects*
- Page 31 in Q&A

Outline



Part I

Research problem

Design problem

Knowledge question

Design cycle

Part III

Theories

Empirical cycle

Part II

- Problem investigation
- Treatment design
- Treatment validation

Part IV

- Problem analysis
- Research setup design & inference design
- Validation
- Research execution
- Data analysis

Part V

Research methods

Appendix A

Checklist for the design cycle

Appendix B

Checklist for the empirical cycle

Main points Chapter 10
Empirical cycle

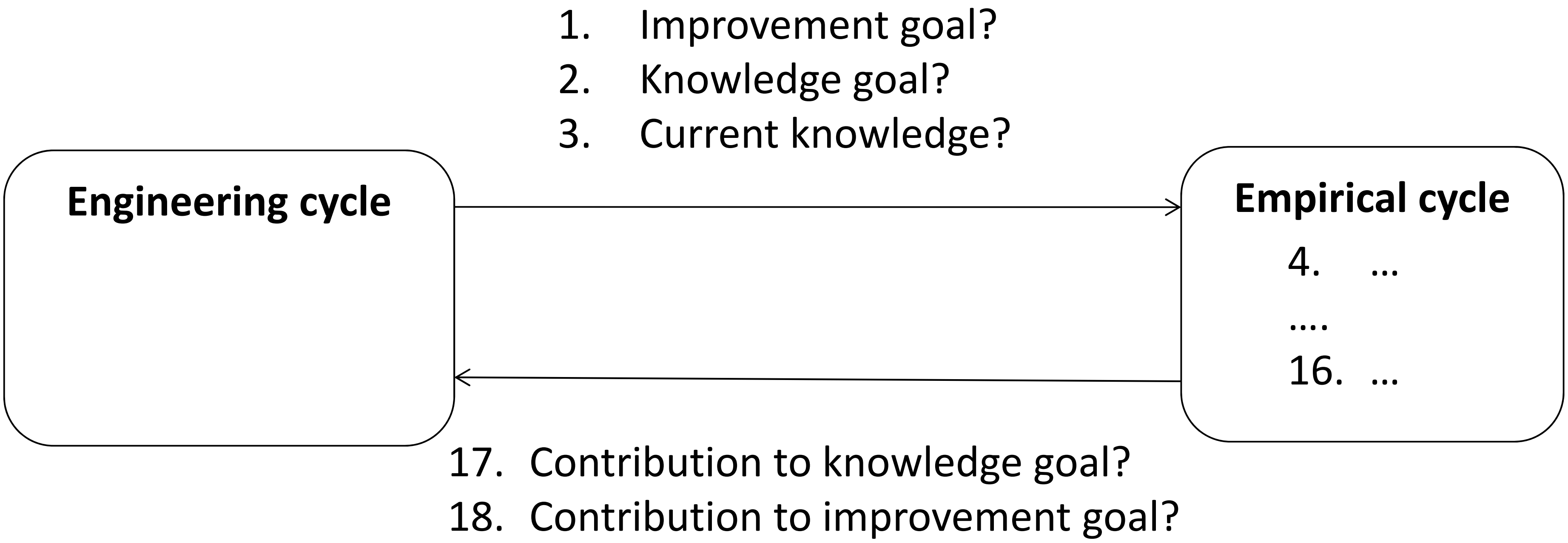
- Empirical cycle is problem-solving cycle aimed at answering knowledge questions
  - **Research context:** improvement and/or curiosity
  - **Problem:** knowledge questions about a population, framed by conceptual framework; current knowledge not sufficient
  - **Design:** Research setup with inference techniques
  - **Validation:** Before executing the design, you check if the research setup supports the planned inferences, is repeatable, and satisfies ethical constraints
  - **Execution:** data collection, unexpected events, maintain a log
  - **Analysis:** description, explanation, generalization, answers, and their validity in view of what actually happened during the execution.

10. The Empirical Cycle

Checklist for researchers, authors, readers

10.1 The context of research

Checklist questions about research context



1. Improvement goal?
2. Knowledge goal?
3. Current knowledge?

Engineering cycle

Empirical cycle

4. …

….

16. …

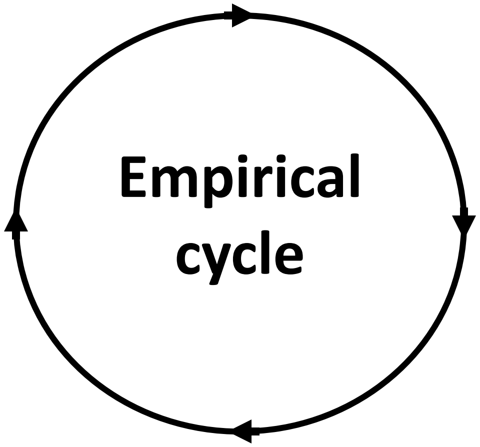
17. Contribution to knowledge goal?
18. Contribution to improvement goal?

- Questions to ask when you
  - Do the research
  - Write a report about the research
  - Read a report about research

10.2 The empirical cycle

Data analysis
12. Data?
13. Observations?
14. Explanations?
15. Generalizations?
16. Answers?

Research execution
11. What happened?



Empirical cycle

Research problem analysis
4. Conceptual framework?
5. Research questions?
6. Population?

Design validation
7. Object of study validity?
8. Treatment specification validity?
9. Measurement specification validity?
10. Inference validity?

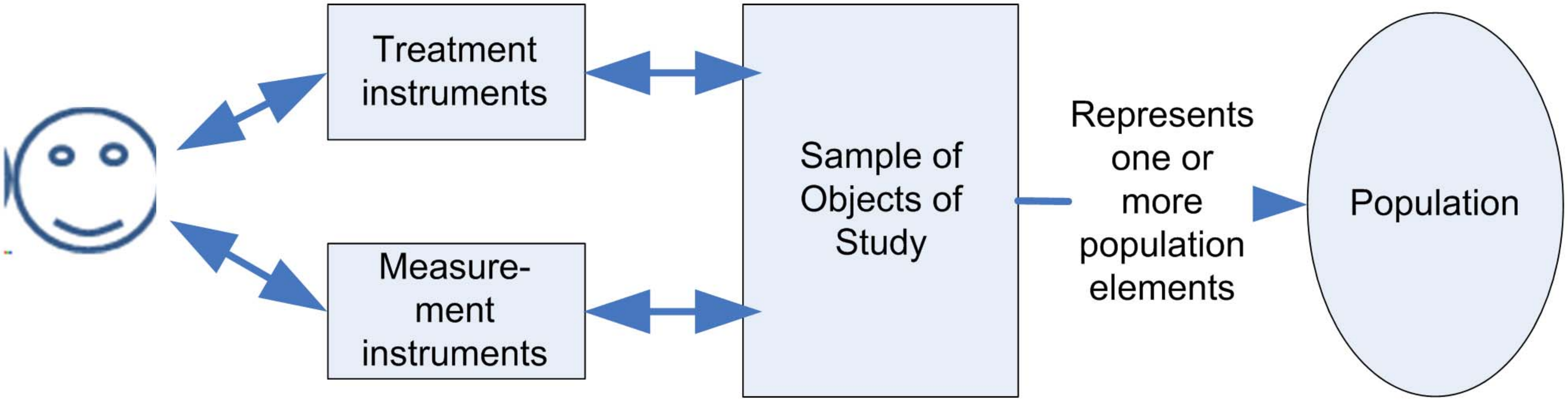
Research & inference design
7. Object of study?
8. Treatment specification?
9. Measurement specification?
10. Inference?

Research setup

10.3 The research problem

4. How are we going to describe the phenomena? Conceptual framework
5. What knowledge questions do we have?
6. What do we know already? Facts, theories

10.4 The empirical research setup



Treatment instruments

Measurement instruments

Sample of Objects of Study

Represents one or more population elements

Population

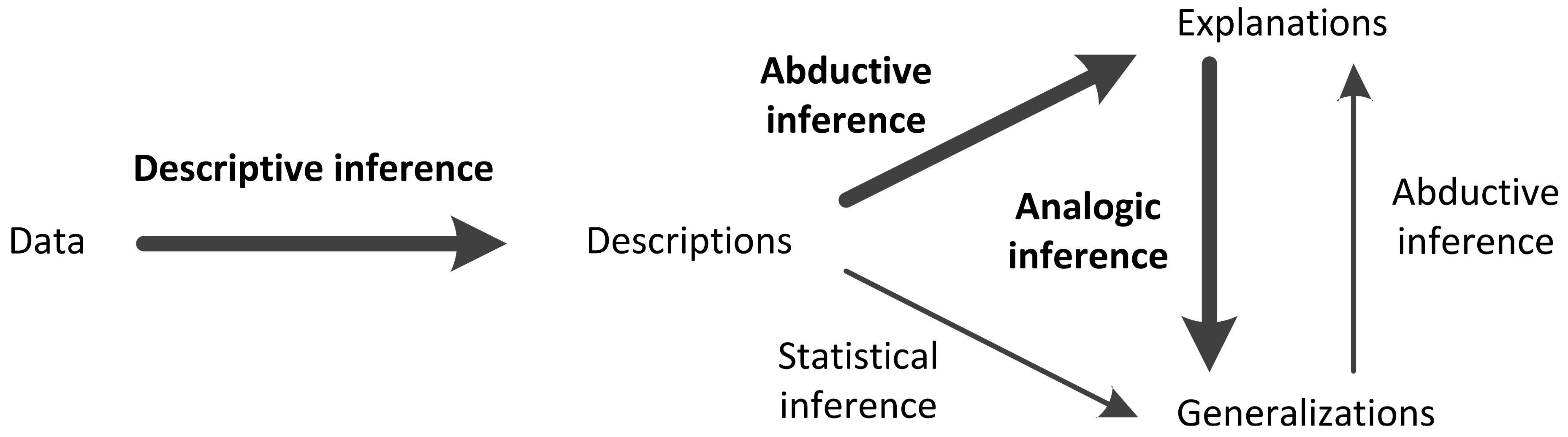
- In case-based research: sample of OoS's studied as a whole
- In case-based research: OoS's studied case by case
- In observational research: no treatment
- In experimental research: treatment

Validity of the research setup

- Validity of the research setup must be argued by providing three arguments.
  - The setup **supports planned inferences** from the data
  - The design is **repeatable** by other researchers
  - The setup is **ethical** w.r.t. people and animals
- These arguments are fallible, but you can still give good (or bad) argument for validity.
- See chapter 11.

10.5 Inferences from data

Case-based inference



Explanations

Abductive inference

Descriptive inference

Data

Descriptions

Analogic inference

Abductive inference

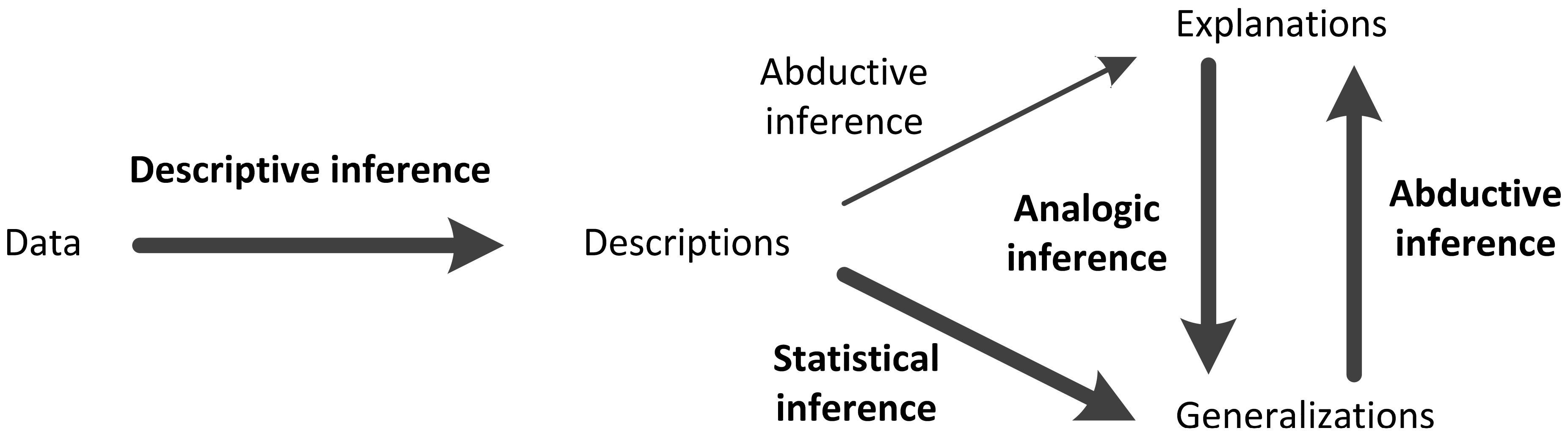
Statistical inference

Generalizations

Case-based inference

1. **Descriptive inference:** Describe the case observations.
   - *In a study of a global SE project, describe the organizarional structure and communication & coordination processes based on data obtained from project documents, interviews, email and chat logs.* **Descriptive validity.**
2. **Abductive inference:** Explain the observations architecturally and/or rationally.
   - *Explain reduction of rework by the capabilities of the cross-functional team in the project.* **Internal validity.**
3. **Analogic inference:** Assess whether the explanations would be true of architecturally similar cases too.
   - *Reason that similar teams will produce similar effects, other things being equal.* **External validity.**

Sample-based inference



Data

Descriptive inference

Descriptions

Abductive inference

Statistical inference

Explanations

Analogic inference

Abductive inference

Generalizations

Sample-based inference

1. **Descriptive inference:** Describe sample statistics.
   - *In an experiment with a new programming technique, describe average #errors in treatment and control groups of students.* **Descriptive validity.**
2. **Statistical inference:** Estimate or test a statistical model of the population.
   - *Estimate a confidence interval of difference of averages in population.* **Conclusion validity.**
3. **Abductive inference:** Explain the model causally, architecturally and/or rationally.
   - *Argue that diftference is due to difference in technique. Expolain by psychological mechanisms.* **Internal validity.**
4. **Analogic inference:** Assess whether the statistical model and its explanation would be true of populations of architecturally similar cases too.
   - *Argue that same effect will be obtained in junior practitioners*. **External validity.**

10.6 Execution and data analysis

11. Execution and data analysis
    - Data collection, storage & management
    - Unexpected events, subject dropout, failing equipment, …
    - Your diary

10.7 The research process

- Research process may iterate over empirical cycle, backtrack and revise earlier decisions, etc.
- **Rule of posterior knowledge:** knowledge produced by research was absent before the research
  - Do not claim to have had knowledge at the start, that you did not have
  - E.g. do not claim that you have tested a hypothesis that you did not have in advance
- **Rule of prior knowledge:** Knowledge present before the research may influence the outcome of research.
  - This is the reason for double-blind experiments
  - E.g. your expectations and beliefs may influence the outcome
- **Rule of full disclosure**
  - Report all events that could have influenced the research outcome.

Assignment chapter 10

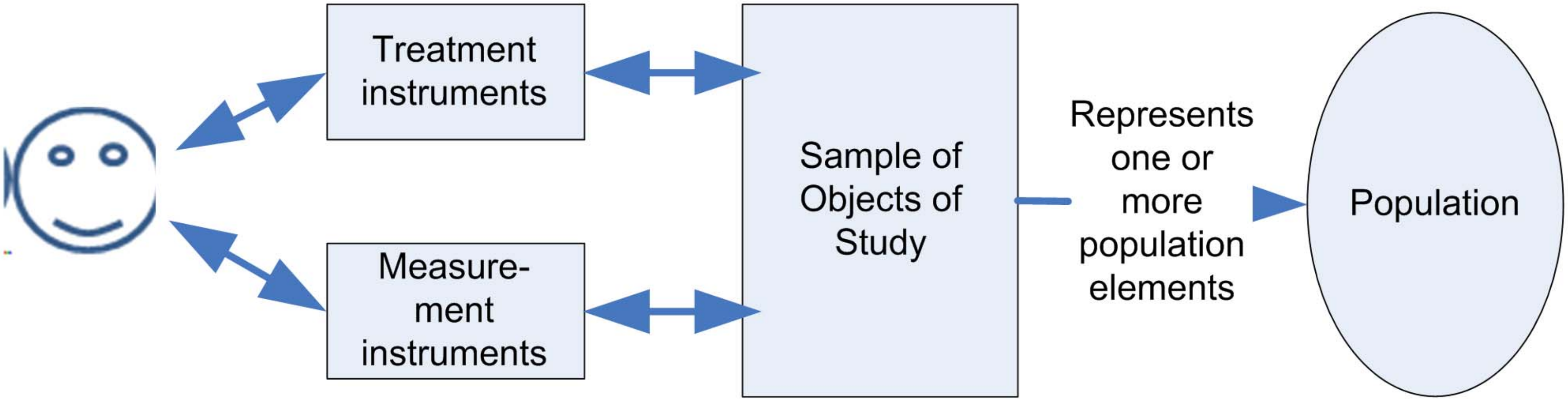
- Joint assignment of chapters 10 and 11. See chapter 11.

11. Empirical Research Design

Main points chapter 11
Empirical research design

- **OoS** is the part of the world that produces the measured phenomena and that the researcher interacts with
- **Samples** of OoS
  - studied sequentially in case-based research,
  - Studied as a whole in sample-based research. Selected from **study population**, which is subset of **theoretical population.**
- **Measurement** is the collection of data about phenomena according to a systematic rule
  - Measured variables have a scale (nominal, ordinal, interval, ratio).
  - Data provenance
- **Treatments** are interventions in the OoS's
  - Statistical terminology: dependent, independent, extraneous, confounding variables
- Inferences & research setup have a **degree of validity** wrt each other

The research setup



Treatment instruments

Measure-ment instruments

Sample of Objects of Study

Represents one or more population elements

Population

Validity

- The research setup must be valid in three ways
  - **Inference support:** it must support your planned reasoning from measurements to answers
    - Degree of support
  - **Repeatable:** other researchers must be able to repeat the research
    - Make information about research design available
  - **Ethical:** People must not be treated unethically in the research
    - Informed consent
    - Rules for cheating and debriefing
    - Procedure for hiding data from subject
    - No harm
    - Fairness
    - Confidentiality

11.1 Object of Study

Object of study

- An **object of study** is a part of the world that the researcher actually interacts with, to learn something about the elements of a population
- Examples
  - *An agile project studied in detail*
  - *A software prototype & environment model used to simulate future implementations*
  - *Students used as models of software engineers*
  - *Some elderly people in one home as model of all elderly people in all homes*
- Population elements or models of population elements
- Natural models or artificial models

Validity of OoS wrt inferences

- For statistical inference:
  - Is chance model of variables defined?
  - Assumptions of statistical routines satisfied?
- For abductive inference:
  - Causal explanations: What are the influences on OoS?
  - Architectural explanations: What is the architecture of population elements? Does OoS have this architecture?
  - Rational explanations: Are goals and motivations of actors observable?
- For analogic inference:
  - What is the architecture of population elements, and does OoS have this architecture?
  - Is it representative of elements of the population?

11.2 Sampling

Sampling in case-based research

- Object of study is a case.
- Cases are studied one by one.
- Generalization is by **analytical induction**:
  - The next case can be selected to *confirm* or to *falsify* the current theory
  - Theory is developed to explain the positive and the negative cases.

Sampling in sample-based research

- Sample is studied as a whole.
- Population
  - **Sampling frame** is list of study population, actually sampled from.
  - **Study population** is subset of entire, **theoretical population**

- Statistical inference from sample to study population assumes (simple) random sampling.

- Analogic inference from study population to theoretical population

Validity of statistical inference

- With (simple) random sampling:
  - Sample mean = population mean + random fluctuation
  - Statistical inference allows you to estimate the size of the random fluctuation, so that you can estimate the population mean.
- With nonrandom sampling:
  - Sample mean = population mean + systematic displacement + random fluctuation
  - To estimate the population mean, you need an estimate of the systematic displacement; which you almost always do not have

11.3 Treatment

Treatments and experiments

- An experimental treatment is a treatment of an OoS by a researcher, performed with the goal of learning about effects of the treatment.

– Statistical terminology:
  - **Dependent variable** is believed to be affected by treatments. Outcome variable.
  - **Independent variable** represents treatments
  - **Extraneous variable** is other variable that *may* affect dependent variable
  - **Confounding variable** is extraneous variable that *does* affect the treatment

Treatment validity

- For statistical inference:
  - Random allocation of treatments to OoS’s?
- For causal inference:
  - Any other possible influence on dependent variable, other than the treatment?
- For analogic inference:
  - Is experimental treatment similar to treatment in the population?

11.4 Measurement

- Measurement is assignment, according to a rule, of a value to a phenomenon denoted by a variable.
- E.g. we can measure
  - *Duration of a project by counting the days from the project approval to the project discharge*
  - *We can measure the size of a program by counting the number of executable lines*
  - *We can meassure customer satisfaction according to a fixed questionnaire*
  - *Etc.*
- Science can only progress if we have measurable constructs.
  - *E.g. speed, momentum, force, etc.*

Scales

- The numbers assigned to a phenomenon must have a scale
- A scale is a data type **plus a real-world interpretation in terms of phenomena**

Qualitative scales

- **Nominal scale**
  - Values represent *identity* of entities, events, etc.
  - Preserves meaning under any bijection
  - Admissable operators: = and ≠
  - The values of a nominal scale can be counted.
    - *Proper names for phenomena. Meaning of data is the same under any bijective replacement of names by other names.*
    - *Identifiers.*
    - *Classifications. Meaning is the same under any bijective change of names of classes.*

Qualitative scales

- **Ordinal scale**
  - Values represent *order*
  - Preserves meaning under any order-preserving transformation
  - Admissable operators: =, ≠, < and >
    - *Preferences on a Likert scale*
    - *Hardness of material*
    - *Ease of use*
    - *Serial numbers if each number given out is higher than the previous one, indicate production order*

Quantitative scales

- **Interval scale**
  - Values represent *degree of difference*
  - Preserves its meaning under multiplication and addition of numbers e.g. aX+b
  - Distances that are equal before transformation, are equal after transformation. So ratios of distances between data points are meaningful. So there is a unit (but no zero).
  - Admissable operators: =, ≠, <, >, + and -
    - *Celcius and Fahrenheit temperature scales.*
    - *Dates from an arbitrary starting point.*
    - *Serial numbers if each number given out is the previous number plus 1.*

Quantitative scales

- **Ratio scale**
  - Values represent *quantity*: The ratio between a magnitude of a continuous quantity and a unit magnitude of the same kind
  - Preserves its meaning under multiplication by a number but not under addition of a number, i.e. aX.
  - There is a unit and a zero.
  - Admissable operators: =, $\neq$, <, >, +, -, * and /
    - *Time in second or in minutes*
    - *Kelvin temperature scale*
    - *Profit in Euros per year.*

Which scale?

- *Entry tickets*
  - *Nominal scale for a lottery*
  - *Ordinal scale for entrance order*
  - *Interval scale for time intervals between entry*
- Depends on our research goal

- Also: The data do not know where they came from. But *we* should know and remember.
  - The data will allow any computation, but we should restrict ourselvbes to the meaningful ones

Symbolic data

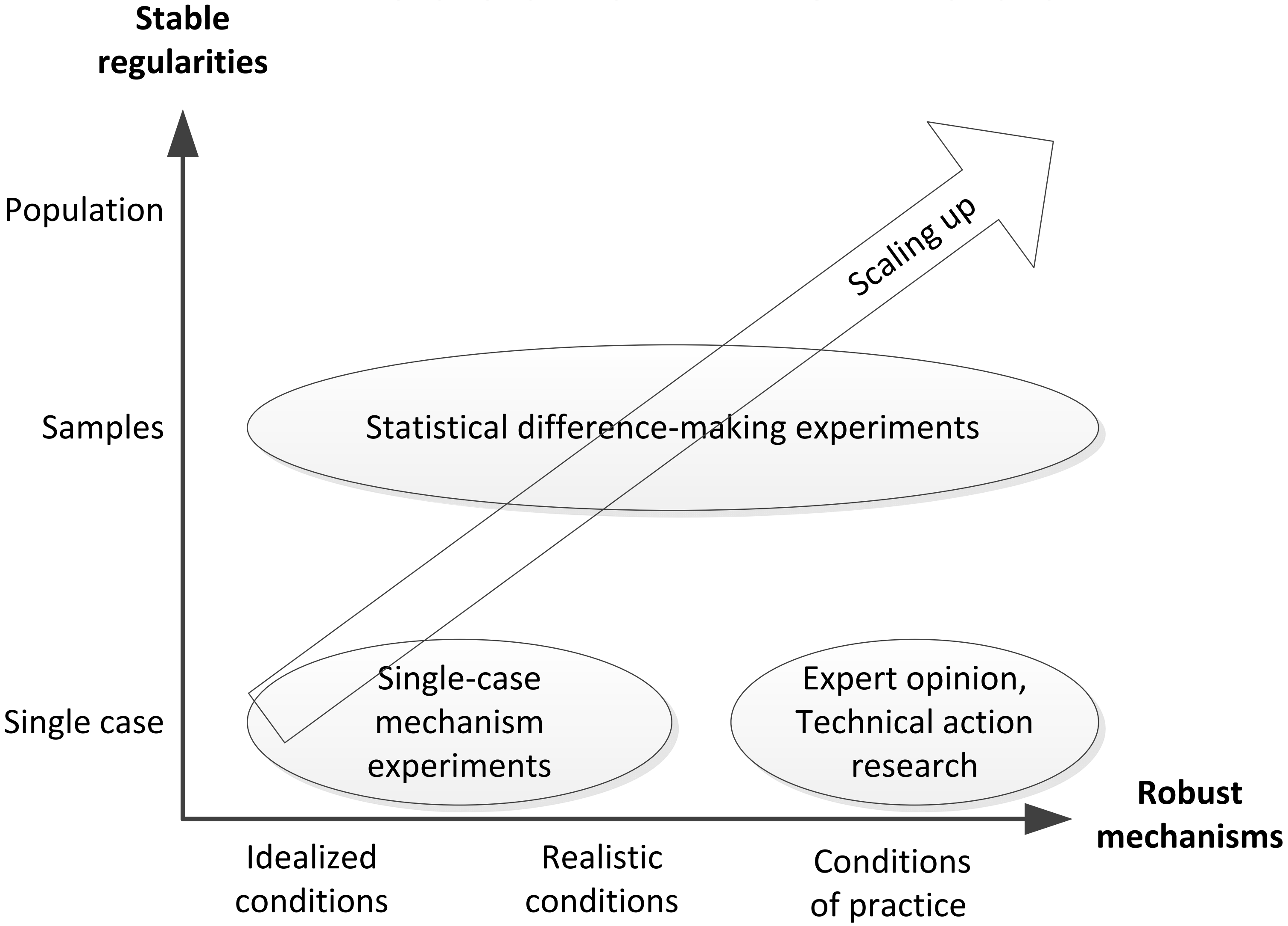
- Written language, spoken language, images, videos, are symbolic data.
- Need to be interpreted by people. Preferably several independent interpreters.
- Interpretations are often codes for parts of the meaning of the data.

Overview of research designs

	Case-based research	Sample-based research
No treatment (observational study)	Observational case study (Chap. 17)	Survey
Treatment (experimental study)	Single-case mechanism experiment (Chap. 18), Technical action research (Chap. 19)	Statistical difference-making experiment (Chap. 20)

- **Observational case study:** study the architecture and mechanisms of one case at a time
- **Single-case mechanism experiment:** Investigate architecture and mechanisms experimentally, one case at a time. (testing, simulation, etc.)
- **Technical action research:** Use an artifact to treat real-world problem, to help a client and learn from this.
- **Statistical difference-making experiments:** Investigate average difference between treating and not treating in random samples

Research methods



Stable regularities

Population

Samples

Single case

Scaling up

Statistical difference-making experiments

Single-case mechanism experiments

Expert opinion, Technical action research

Robust mechanisms

Idealized conditions

Realistic conditions

Conditions of practice

Assignment of chapters 10 and 11

- Joint assignment
- Broenink (2014) - *Finding Relations Between Botnet C&Cs for Forensic Purposes*
- Page 38 in Q&A