Introduction to Design Science Methodology

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Design science

• Design science is the design and investigation of artifacts in context

• Examples
  – Design and investigation of agent-based route planning algorithms
  – Design and investigation of goal-oriented enterprise architecture design method
Design science versus natural science

• Design science is **solution-oriented**
  – *How to do agent-based route planning*
  – *How to design an enterprise architecture aligned to business goals*

• Natural science, social science are **problem-oriented**
  – *Observational studies of requirements engineering in agile projects*
  – *Observational studies of patterns of evolution of groupware systems*
  – *Experimental studies to understand how software engineers understand UML*
The engineering cycle

- Real-world problem investigation
- Treatment design
- Design validation
- Treatment implementation
- Real-world implementation evaluation

Stakeholders, goals, phenomena, evaluation, diagnosis.

If hypothetical real-world problem: Stakeholders do know they are stakeholders …
The engineering cycle

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- Treatment design
- Design validation
- Treatment implementation
- Real-world implementation evaluation

You design the artifact in order to create a treatment for the problem context

- Interaction between pill and patient
- Interaction between Software and its Context
- Interaction between method and its context of use

Treatment = interaction between artifact and context
The engineering cycle

- Real-world problem investigation
- Treatment design
- Design validation
- Treatment implementation
- Real-world implementation evaluation

Typical research methods for treatment validation:
- Expert opinion (e.g. focus group)
- Simulation: artifact prototype applied in simulated context
- Field experiment: artifact prototype applied in real context to see what happens
- Technical action research: artifact prototype applied in real context to help a client
The engineering cycle

• Real-world problem investigation
• Treatment design
• Design validation
• Treatment implementation
• Implementation evaluation

Since the problem is real-world, this is transfer to the real world! Possible sequel to research project, but not part of research project.
The engineering cycle

- Real-world problem investigation
- Treatment design
- Design validation
- Treatment implementation
- Real-world implementation evaluation

Find out what really happened after a real-world implementation:
Phenomena: Artifact & Context → Effects?
Evaluation: Effects satisfy Criteria?
Engineering cycle

Design implementation
Choose a treatment!
Transfer to practice!

Implementation evaluation = Problem investigation
• Stakeholders? Goals?
• Phenomena? Causes, mechanisms, reasons?
• Effects? Contribution to Goals?

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

Treatment design
• Specify requirements!
• Contribution to goals?
• Available treatments?
• Design new ones!

Legend:
? Knowledge questions
! Tasks

About 15 minutes
Design cycle

Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Phenomena? Causes, mechanisms, reasons?
- Effects? Contribution to Goals?

Typically in a research project you iterate over design and validation many times

Legend:
? Knowledge questions
! Tasks

Treatment design
- Specify requirements!
- Contribution to goals?
- Available treatments?
- Design new ones!

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

Real-world implementation is not part of your research project

Choose a treatment!
Transfer to practice!

Design implementation

About 15 minutes
Microtutorial
Some research projects focus on this (ending with a proposed treatment)

- Stakeholders? Goals?
- Phenomena? Causes, mechanisms, reasons?
- Effects? Contribution to Goals?

Some research projects focus on this (starting with a tiny problem investigation)

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

Design cycle

Implementation evaluation = Problem investigation

Legend:
? Knowledge questions
! Tasks

Design cycle

Treatment design

• Specify requirements!
• Contribution to goals?
• Available treatments?
• Design new ones!
Research problems in design science

To design an artifact to improve a problem context

Problems, Artifacts

To answer knowledge questions about the artifact in context

Knowledge

Solve using the engineering cycle.

- “Design a DoA estimation system for satellite TV reception in a car.”
- “Design a multi-agent aircraft taxi-route planning system for use on airports”
- “Design an assurance method for data location compliance for CSPs”
- “Is the DoA estimation accurate enough?”
- “Is this agent routing algorithm deadlock-free?”
- “Is the method usable and useful for cloud service providers?”

The design researcher iterates over these two activities

About 15 minutes Microtutorial
You have given empirical evidence that (Artifact x Context → Effects) in the real world.

You have given a credible analytical argument that (Artifact x Context → Effects), illustrated by a small example, without having done empirical research to support this argument.

Validating new technology

Stable regularities

Population

Samples

Idealized conditions

Realistic conditions

Conditions of practice

Laboratory credibility

Street credibility

Scaling up

Robust mechanisms
Research methods

Stable regularities

Population

Samples

Single case

Idealized conditions

Realistic conditions

Conditions of practice

Single-case mechanism experiments (e.g. simulation)

Robust mechanisms

Expert opinion, Technical action research

Statistical difference-making experiments

Scaling up
The empirical research cycle

- This is the rational decision cycle applied to answer knowledge questions (empirical research questions)
  - Knowledge problem investigation
  - Research design
  - Design validation
  - Research execution
  - Results evaluation
• Knowledge problem investigation
• Research design
• Design validation
• Research execution
• Results evaluation

Theoretical framework, Research questions, Target of generalization (a.k.a. population)
• Knowledge problem investigation
• Research design
• Design validation
• Research execution
• Results evaluation

Decisions about Object of study, measurement and treatment, and inference. Possible designs:
- Survey,
- Observational case study,
- Experiment,
- Action research,
- Simulation,
- ...
• Knowledge problem investigation
• Research design
• Design validation
• Research execution
• Results evaluation

Would this really answer our knowledge questions?
Risk assessment of doing the wrong thing to answer the questions
• Knowledge problem investigation
• Research design
• Design validation
• Research execution
• Results evaluation

Do the research as planned. Unexpected things may happen!
• Knowledge problem investigation
• Research design
• Design validation
• Research execution
• Results evaluation

How can we now answer our knowledge questions? Risk assessment of answering the questions incorrectly
Analysis of results
12. Data?
13. Observations?
14. Explanations?
15. Generalizations?
16. Answers?

New research problem

Research execution
11. What happened?

Empirical cycle

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

Research design validation
7. Object of study justification?
8. Treatment specification justification?
9. Measurement specification justification?
10. Inference justification?

Research design
7. Object of study?
8. Treatment specification?
9. Measurement specification?
10. Inference?
• Where are you?
  – Problem investigation / implementation evaluation
  – Design & validation
  – Empirical research

• What are your research goals?
  – Focus


